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ABSTRACT

Presented is a collection of thoroughly-tested discrepant events designed for use in science classes. These events have been organized into 17 chapters grouped into four sections: Environment (5 chapters), Energy (7 chapters), Forces and Motion on Earth and in Space (3 chapters), and Living Things (2 chapters). The following information is provided for each discrepant event: chapter science concept, science sub-concept or science properties, title of event, materials needed, sketch of materials set-up, step-by-step explanation of procedure to be followed, key questions to be asked, and explanation providing background information for the teacher.
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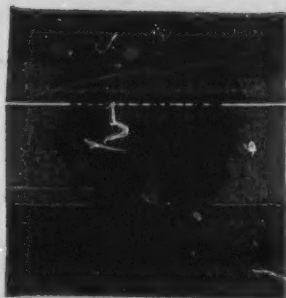
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Invitations to Science Inquiry

Tik L. Liem

*St. Francis Xavier University
Department of Education*



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To Bert,

Jeffrey, Ruby, Dave, and Clifford

Preface

This book is written and designed for teachers of science, particularly for those at the upper elementary and junior high or intermediate level, for college students preparing to teach science, and for all those individuals who are interested in science.

In the teaching of a science concept, it is most essential for the teacher to arouse the students' curiosity. Unless the student wants to know what the teacher has to say, it is most likely that time and effort in trying to teach the student would have been completely wasted. The first task of a teacher is to attract the attention of the student. This goes for all levels of learning, whether it is primary grade or college. A student without interest is the desperation of any teacher. In fact, the main objective of formal education is the arousing of the students' interest, if nothing else. Once curiosity is aroused the student will learn much more on his/her own than the teacher can ever teach him/her. Learning only takes place if the student wants to learn.

The use of discrepant events in the teaching of science is one of the best methods to do just that: to arouse interest and curiosity. The discrepant or counterintuitive event in science, sometimes also called the *mind-capture* or the *intuition-offending* event, is an occurrence or happening which goes counter to what one thinks likely. This event is set up in such a way that it poses a question to the student and asks him/her to come up with the explanation. There is evidence that students will retain science concepts longer when they were engaged in experiencing counterintuitive events. This book is a collection of thoroughly tested discrepant events. They can be used to initiate or sustain a lesson on virtually any topic of science at the upper elementary or intermediate level. They can also be used as reinforcement activities for the students or as challenging problems for further inquiry. Each of the events is a focus for inquiry teaching, a most appropriate way of reflecting the true nature of science in the classroom. The students are required to put into practice most of the science processes when engaged in inquiry.

The description of each of the discrepant events is organized in such a way as to provide the teacher with the maximum guidance for conducting a science inquiry lesson. Emphasis has been placed on the use of simple material so that most of the events may be carried out with things that are found in everyday life or may be bought in local stores.

Although each of the events have been tested and the procedure, questioning, and explanation constructed by the author, many of the ideas have come, probably often without realizing it, from others. The author is very conscious of his indebtedness to numerous persons--mostly teachers, colleagues, and students--and wishes it were possible to thank each one individually. Perhaps his gratitude is best expressed by his desire to share with a larger audience any contribution he has made as a result of their inspiration.

Tik L. Liem
St. Francis Xavier University
Antigonish, Nova Scotia, Canada B2G 1C0

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Introduction

The dedicated science teacher always searches for new demonstrations or activities that will arouse students' interest and enhance their learning experiences. It has been felt by the author in working with pre- and in-service teachers, that a simple well-organized teachers' guide for science demonstrations and science inquiry in class is much needed: one that can be used as a resource to initiate, sustain, and extend the process of science inquiry in and beyond the classroom.

This book, unlike any other science methods book offered, is a storehouse of invitations to inquiry of discrepant events, which are excellent motivators in the teaching of science. It is most suitable for teaching science at the upper elementary and intermediate levels, although some of the events are simple enough for the lower elementary grades, and some are complex enough to be dealt with at senior high levels. It is especially designed for teachers with a limited amount of spare time and background in science, and for those who are teaching in schools with limited science facilities.

Purpose

The main and foremost aim of this book is to aid the teacher of science in conveying and presenting a science concept to the student in such a way that the concept is retained by the student.

Rationale

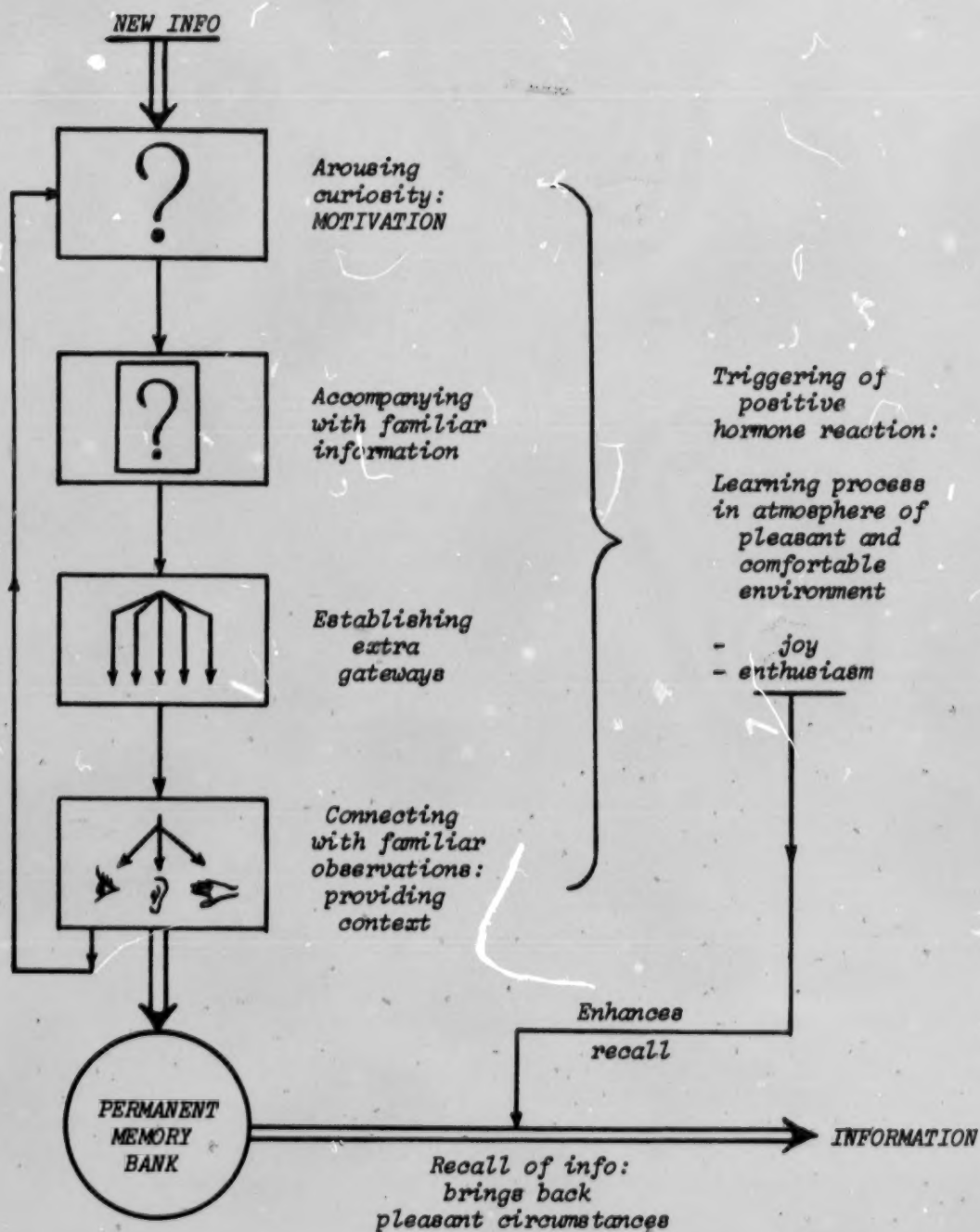
In considering the learning process it was found that several factors are playing an important role to achieve concept retention. These factors consist of the following: (see scheme 1 on page 2)

1. The arousing of curiosity: motivation.
2. The accompanying of new concepts with familiar information.
3. The use of more than one gateway into the brain.
4. The presentation of the new concept in a relevant context.
5. The presence of an environment of joy and enthusiasm surrounding the learning process.

The discrepant event in science meets all these requirements and when used in the right way for teaching a science concept, will enhance the retention of the concept. The discrepant event creates a dissonance between what the mind expects to happen and what is actually being observed. Festinger's theory of cognitive dissonance proposes that:

- a. the existence of dissonance being psychologically uncomfortable will motivate the person to try to reduce the dissonance and achieve consonance, and
- b. when dissonance is present, in addition to trying to reduce it the person will actively avoid situations and information which would likely increase the dissonance.

Scheme 1. PROCESS OF INFORMATION RETENTION AND RECALL



Since it is impossible to change what is physically observed, the only other alternative to achieve consonance is to begin to seek information which will logically explain the occurrence. At the moment that this information seeking begins, learning is taking place. It is the discrepant event, sometimes called the intuition-offending or the counterintuitive event, or the mind-capture, that will arouse curiosity and trigger the seeking of information to achieve consonance. The learner, once interested to find a logical explanation to the event, will attempt to do this on his/her own.

Science teachers are constantly looking for these curiosity arousing demonstrations or activities, but when trying to use them they are often hampered by the unavailability of rather elaborate equipment suggested and the limited time the teachers have to prepare for such demonstrations.

It is the purpose of this book to assist the science teacher to bring science into the classroom through the following features:

1. It is a compilation and storehouse of selected curiosity arousing discrepant events, which when used will save the teacher from trying to find the appropriate demonstration or activity in different texts.
2. It has a simple format and is organized in such a way that teachers can find relevant demonstrations or activities in a particular topic very quickly.
3. Each event is provided with an illustration, a step by step procedure, a set of questions, and an explanation. This will give the teacher an immediate insight of the material set-up and the conducting of the science inquiry.
4. It emphasizes the use of simple materials, which largely may be acquired in the home and/or local stores. This will bring the teacher to use the discrepant events more readily in his/her regular science classes.

Teaching Strategy

In order to achieve an atmosphere of inquiry in class it is important that the teacher presents the discrepant event as a science problem to be investigated. The intuition-offending event must be presented to the learner in such a way that the science principle underlying the event is not immediately revealed. The teacher should in general lines follow the procedure below:

1. Present to or engage the learner with the discrepant event by describing or commenting on the operations only and not mentioning the reasons for the occurrence to happen. In other words the teacher can tell the student what he/she is doing and what materials he/she is handling, but not why something is happening.

- 4
2. Ask the learner questions that eventually will lead him/her to the main reason of the occurrence. In doing this the students will be engaged in the science processes of observing, measuring, inferring, interpreting data, indentifying and controlling variables, hypothesizing, and experimenting.
 3. Participate the learner in similar counterintuitive activities illustrating the same science concept. Students can work in pairs or in groups of three or more when material is only available in limited quantities.

The main objective of this participation is to reinforce the learning of the concept dealt with. It is essential that the presentation of the intuition-offending demonstration or activity takes place under the following conditions:

- a. The event should confront the observer with a perplexing problem. It should be presented almost like the way a magician would do a magic act.
- b. The event should be based on some object or principle that is familiar to the learner.
- c. The learners should have the opportunity to observe as well as carry out the event themselves; in other words they should be able to totally experience it.
- d. When dealing with the concept underlying the event, examples and applications of the concept in our daily life should be mentioned to make it more meaningful to the learner.
- e. The teacher should show genuine enthusiasm in presenting the puzzling event and the subject matter in general.

When all the above elements are present during the learning process, the student will be able to store new information with much more ease. The learning experience becomes more meaningful and enjoyable, resulting in a much better retention of the science concept. The recall of the stored information will bring back all the pleasant circumstances during which it was learned. This makes the recalling process a much effortless one.

The above conditions for learning a science concept may be attained when the teacher is genuinely showing concern for his/her students, uses discrepant events to initiate science inquiry, and most importantly is enthused about what he/she is doing. Once this optimum condition is reached students and teacher will enjoy the teacher-learning process to a much greater extent.

Format

The book is organized in such a way that it offers to teachers the optimum guidance for teaching science concepts and engaging the students in science inquiry. The chapters of the book are organized under four sections: Environment, Energy, Space and Forces, and Living Things. Each section is preceded by a short introduction providing the teacher with some information on the science concepts to be dealt with in the chapters.

The discrepant events, making up the main body of each chapter, are preceded by a list of objectives. These are stated in behavioral terms in order that student and teacher may work towards achieving these behaviors.

The discrepant events are invitations to inquiry, which are all fitted on one page each, for simplicity in format and easy location. Each event is consistently constructed in the following format:

1. Upper left corner: Chapter Science Concept.
2. Upper right corner: Science Sub-concept or Science Properties.
3. Intriguing, curiosity arousing title of event.
4. Materials needed for the demonstration or activity.
5. Sketch of materials set-up.
6. Procedure, in step by step fashion.
7. Questions for teacher's use during the demonstration.
8. Explanation, providing background information for the teacher.

The book ends with a list of references in which similar or more detailed information may be obtained. A general index follows the reference list, where users of the book may find concepts and sub-concepts and the relevant events that are appropriate to use in teaching those concepts to students.

SECTION I

ENVIRONMENT

This section consists of five chapters dealing specifically with the properties of matter in our immediate environment. This includes the following:

1. The air around us in its stationary form. It occupies space, it exerts pressure, it expands when heated, it has weight, and it contains oxygen.
2. The air around us when it moves or flows. Flowing air exhibits properties that are unexpected, namely a lower pressure compared to stationary air, and the faster the flow, the lower the pressure exerted.
3. The weather and all the variables influencing it, like: high and low pressures, the wind direction and velocity, the temperature and humidity, altitude and climate, and location on earth.
4. The characteristics of matter. This chapter deals with the molecular spacing of matter, cohesion and adhesion, surface tension, the three states of matter, boiling and melting point.
5. The chemicals in our environment and how they behave. Acids and bases, salt formation, catalytic reactions, spontaneous combustion, substitution reactions and electrochemical reactions are dealt with.

Science



for
Young and Old

CHAPTER 1

WHAT ARE THE PROPERTIES OF AIR ?

OBJECTIVES

After dealing with and studying the concepts in this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

- Air exists all around us.
- Air occupies space.
- Air exerts pressure.
- Air expands when heated, and rises as a result.
- Air contains oxygen.
- Air has weight.

1.1. THE AIR CATCHER

- Materials:
1. A medium plastic garbage bag
 2. One plastic sandwich bag per student



Procedure:

1. Take the medium size garbage bag, open its mouth and ask the students: "What is in the bag?" (Anticipated answer: 'nothing').
2. Move the bag now with two hands back and forth (like wanting to catch a bug in the bag), then quickly close the mouth of the bag with a twisting motion.
3. Ask the students: "What do I have in the bag now?"
4. Distribute the sandwich bags to the students and let them try to catch air in their own seats, without blowing into the bag.

Questions:

1. What was filling the bags?
2. Can we catch air under the bench or behind the door?
3. Is the air the same everywhere?
4. How else can we fill the bag?
5. Would the material in the bag be the same if we blew in it?
6. How can we keep the bag inflated?
7. What would happen if we hit the inflated small plastic bag with the palm of the other hand?

Explanation:

Air is found everywhere. The plastic bags may be filled with air above the table, under the table, behind the door or anywhere else with the same air. The bags can also be inflated by blowing in them, but then the bags would contain exhaled air, which has a higher percentage of carbon dioxide (CO_2) and more water vapour.

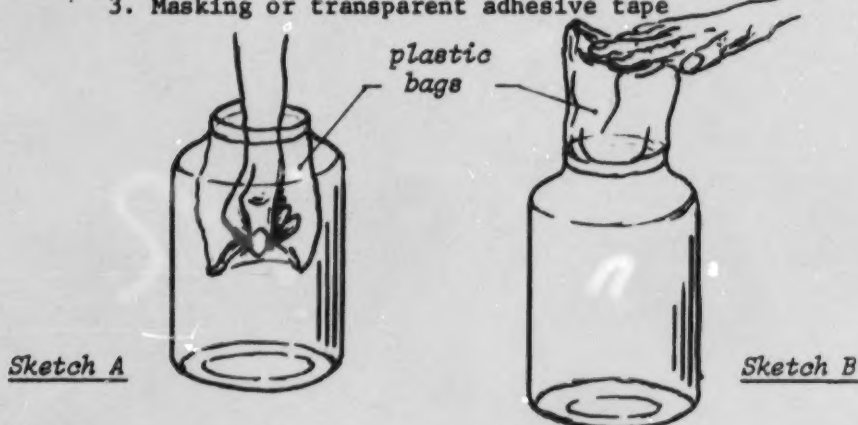
When the filled bag is slammed between the two palms of the hands it will burst with a loud pop. This explosion is caused by the sudden expansion of the air rushing out of the torn plastic bag.

AIR

OCCUPYING SPACE

1.2. THE BOTTLE AND THE BAG

- Materials:
1. One or two plastic sandwich bags
 2. One or two large wide-mouthed glass jars (pickle jars)
 3. Masking or transparent adhesive tape

Procedure:

1. Invert the bag over the mouth of the jar, blow a little air in the bag such that it stays inflated over the jar (see Sketch A).
2. Tape the bag air-tight against the jar.
3. Now ask one of the students to push the bag into the jar (without tearing it): It won't work!
4. Place another plastic bag inside another wide-mouthed jar (or use the same bag and jar) and let the edge of the bag hang over the jar rim (see Sketch B).
5. Tape it air-tight against the jar and let a student try and take the bag out of the jar (without tearing it): It won't work!

Questions:

1. Before putting the plastic bag on the jar, ask: "What is inside the jar? Inside the plastic bag?"
2. What is holding the bag out of the jar? (when trying to push it in).
3. What is holding the bag inside the jar? (when trying to take it out).
4. How could we get the bag inside the jar without making a hole in it?

Explanation:

It is the air occupying the space in the jar which kept the bag from going inside after it had been taped air-tight against the jar. In trying to push the bag in, the pressure increased (because the volume decreased) and this held the bag out.

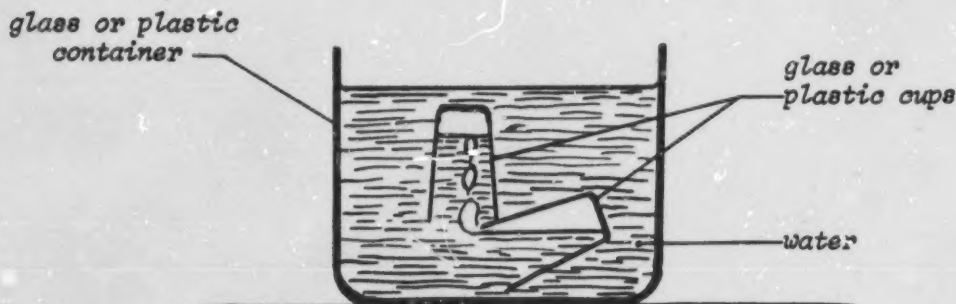
When trying to take the bag out of the jar, the air pressure inside the jar decreased, because the volume increased, and this kept the bag inside. The outside air pressure kept the bag inside the jar. We encounter the first situation often when we try to fold up a plastic air mattress or inflatable plastic toy.

AIR

OCCUPYING SPACE

1.3. POUR AIR UNDER WATER

- Materials:
1. Two glass or transparent plastic cups
 2. A large transparent container (a small aquarium)

Procedure:

1. Fill the plastic or glass container about 3/4 full with water.
2. Hold one cup in each hand upside down and push them under water.
3. Fill one of the cups with water by holding it slanted and thus releasing the air bubbles (do not leave any bubbles).
4. Now we have one cup filled with water in the one hand, and one cup with air in the other (still under water).
5. Now push the cup with air a little lower than the other, and pour the air in the other cup by slowly slanting it (catch the air bubbles: see Sketch).
6. We can repeat this pouring from one cup into the other.

Questions:

1. Before immersing the cups, ask: "What is in the beakers or cups?" (anticipated answer: 'nothing').
2. At the time of immersing the inverted cups, ask: "Why doesn't the water enter the cups?"
3. Why do the bubbles rise and not sink?
4. Can the cup with water be held partly above the water level without letting the water run out of the cup?

Explanation:

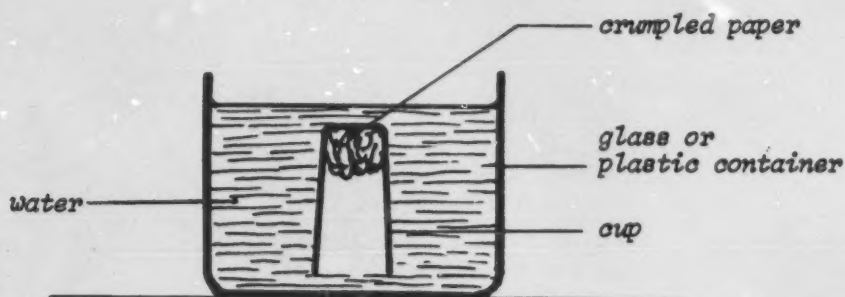
Air occupies space and also the space in the cups. At the time the cups were immersed under water, they were filled with air, and that is why the water could not enter the cups. By holding one cup slanted the air bubbles were free to escape and thus the water could take its place. Air is much lighter in weight than water and that is why air bubbles rise and not sink in water. The water-filled cup can be held above the water level without letting the water run out, because the atmospheric pressure is pushing on the water surface.

AIR

OCCUPYING SPACE

1.4. KEEP PAPER DRY UNDER WATER

- Materials:
1. A dry glass or transparent plastic cup
 2. A large beaker or transparent plastic container (large enough to fit a person's hand)

Procedure:

1. Fill the large container about 2/3 full with water.
2. Crumple a piece of dry paper and squeeze it to the bottom of the glass or plastic cup.
3. Invert the glass (making sure that the crumpled paper stays up in the cup) and immerse it completely under water, holding it as vertically as possible.
4. Take the cup back out of the water and let the water drip off (do not shake off!).
5. Take the crumpled paper out of the cup with a dry hand and let the students feel and check whether it is dry or not.

Questions:

1. Before inserting the crumpled paper, ask: "What is in the cup?" (anticipated answer: 'nothing').
2. Before immersing the glass under water, ask: "What else beside the paper is in the cup?"
3. While immersing the cup: "Why doesn't the water enter the cup?"
4. Why does the paper have to be crumpled?

Explanation:

Air is *space occupying*. The glass is therefore filled with air, no matter whether it is right side up or upside down. Besides the crumpled paper there was air in the cup. This is why the water could not enter the cup during the immersion process. The paper stayed therefore completely dry.

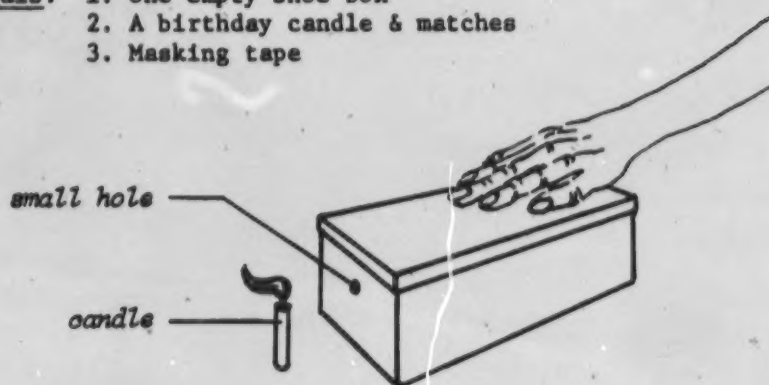
Applications of this characteristic of air can be found when people have to work under water. Air is then pumped in and around the area where the people are working, enclosed by a water-tight wall.

AIR

OCCUPYING SPACE

1.5. THE EMPTY BOX CANDLE SNUFFER

- Materials:
1. One empty shoe box
 2. A birthday candle & matches
 3. Masking tape

Procedure:

1. Show the open shoe box to the students and ask: "What is in the box?" (anticipated answer: 'nothing').
2. Make a small hole in the side of the long end of the box (about $\frac{1}{2}$ cm in diameter) at the same height from the bottom as the candle length, and tape the top to the box.
3. Light the candle and place it about 5 cm away from the box in front of the hole (see Sketch).
4. Hit the box top with a sudden tap with the open hand (make sure that the hole is in line with the candle flame).
5. The lighting and snuffing of the candle may be repeated by doing points 3 and 4.

Questions:

1. What was blowing the candle flame out?
2. What did the tap do to the volume of the box?
3. How far can you hold the candle from the box and yet be blown out?
4. What would happen to the flame if you pushed the box top in gently instead of giving it a sharp tap?

Explanation:

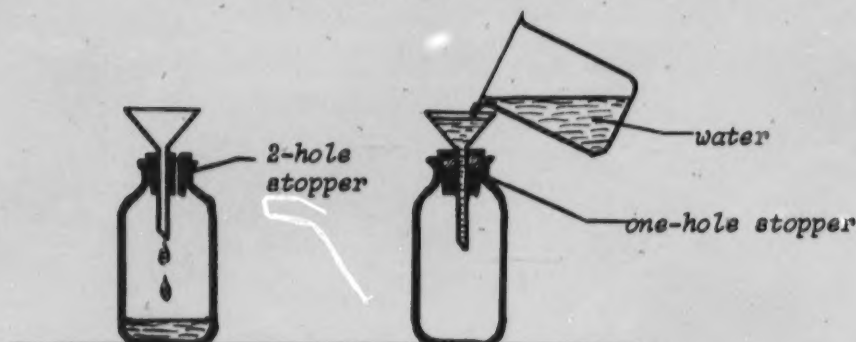
The shoe box is *occupied with air* and by tapping the top of it, the air was forced through the little hole, blowing the candle flame out, just like when we pucker up our lips to blow out a candle. By tapping the box, the volume of it suddenly becomes smaller for a short moment and this action forces the air out. Pushing the box in gently is like blowing very lightly against the flame. This demonstration shows that air is *occupying all the space* around us, also in an 'empty' box.

AIR

OCCUPYING SPACE

1.6. THE REFUSING FUNNEL

- Materials:
1. Two identical glass or plastic funnels with narrow stem
 2. One two-hole stopper & one one-hole stopper
 3. Two identical empty jars or bottles

Procedure:

1. Set up the funnels with the stoppers on the bottles as shown in the sketch above (do not tell that one of the stoppers has two holes).
2. Fill the funnels with water: in one the water will run through (2-hole stopper) and in the other the water will stay in the funnel.
3. Take the bottle with the 2-hole stopper by the neck and put casually the forefinger on the open hole, and pour water in the funnel.
4. Take the bottle with the 1-hole stopper, squeeze the stopper open and the water will run through.

Questions:

1. Before pouring the water: "What is in the bottle?"
2. Why is the water only running through in one bottle?
3. After step 3 of procedure: Why is this funnel now also refusing?
4. What is holding back the flow of the water?
5. Before doing step 4 of procedure, ask: "How can we let the water run through this funnel?"

Explanation:

The bottles were filled with air in the first place. In the bottle with the two-hole stopper the air can escape through the second hole and the water will run through. But in the bottle with the 1-hole stopper, there is no way for the air to escape and this will hold back the water.

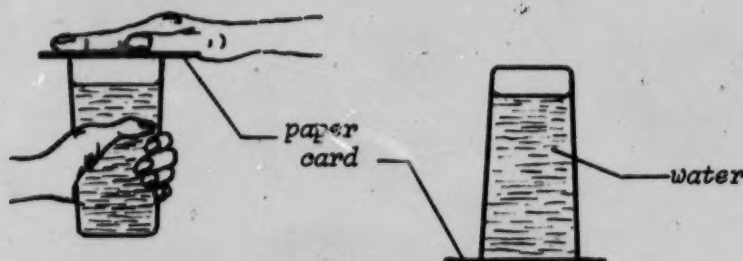
An example of this phenomenon we find when trying to fill a perfume bottle with water or other liquid, or any narrow mouthed bottle with water by holding it under a large stream of water from the tap. There is only one passage way for the water to come in and for the air to go out, in other words, the air is blocking the way for the liquid to come in.

AIR

EXERTING PRESSURE

1.7. THE INVERTED GLASS OF WATER

- Materials:
1. A transparent glass or plastic cup
 2. A paper card (slightly larger than the mouth of the cup)

Procedure:

1. Fill the cup half way or full with water.
2. Place the paper card on the cup.
3. Put one hand on top of the card and invert the cup holding the card in place (do this over a sink or large container to catch any water drippings; also make sure that the hand holding the card is dry).
4. Take the hand that was holding the card slowly away.

Questions:

1. Why does the paper have to be rather stiff?
2. Why do we have to make sure that the hand holding the card on the cup is dry? What will a wet hand do?
3. What is keeping the water in the inverted cup?
4. Can we hold the cup slanted without letting the water pour out?
5. Will we be able to do the same thing with other liquids? (f.i. alcohol, oil, carbonated drink, etc.?)

Explanation:

When the cup is completely filled with water, there is no air left in the cup and thus no air pressure. The inverted cup can therefore hold the water up, because the *atmospheric pressure* is working against the under-side of the cup.

In case of a partially filled cup of water, we can explain it as follows: During the process of inverting, some of the water is dripping out, this increases the volume of the air pocket without increasing the amount of air, thus decreasing the pressure of the air pocket above the water. Again, the *atmospheric pressure* is therefore larger and thus holding the water inside the cup.

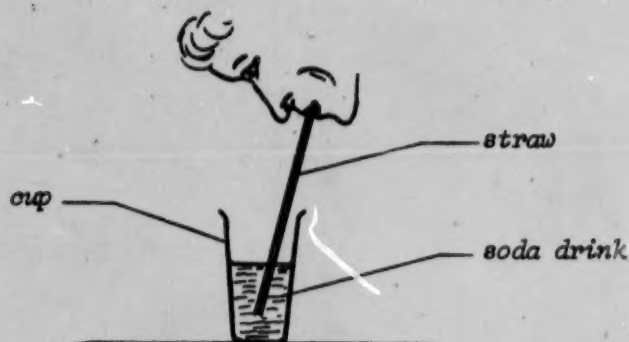
Alcohol and oil will also be held up inside the inverted cup, but the carbonated drink will not, because the carbon dioxide exerts pressure inside the glass above the liquid and prevents a partial vacuum from forming.

AIR

EXERTING PRESSURE

1.8. THE STRAW DRINKING RACE

- Materials:**
1. Two identical drinking straws (one punctured with a few needle holes over the whole length).
 2. Two small cups and some soda drink.

**Procedure:**

1. Fill the two small cups halfway with soda pop.
2. Ask two students to come up and comment: "Who would be the better 'sucker'?", and give each of them a straw (one of them with holes in it, but do not mention this).
3. Let them start drinking (sucking) on the count of three.
4. Give another pair of students a turn to race (the one who has the straw with the holes always loses).

Questions:

1. What makes the liquid go up the straw when we drink?
2. Why is it so hard to drink through a leaky straw?
3. What do we actually create when we suck through a straw?
4. Would we be able to drink through a straw if there was no air pressure around us?
5. Would an astronaut in space or on the moon be able to drink liquid through a straw?

Explanation:

By sucking we are creating a partial vacuum or a lower pressure in the straw above the liquid that we drink. The higher pressure in the atmospheric air pushes the liquid up the straw in our mouth.

The student with the leaky straw sucks in air and thus cannot create a vacuum above the liquid, so the liquid is not pushed up.

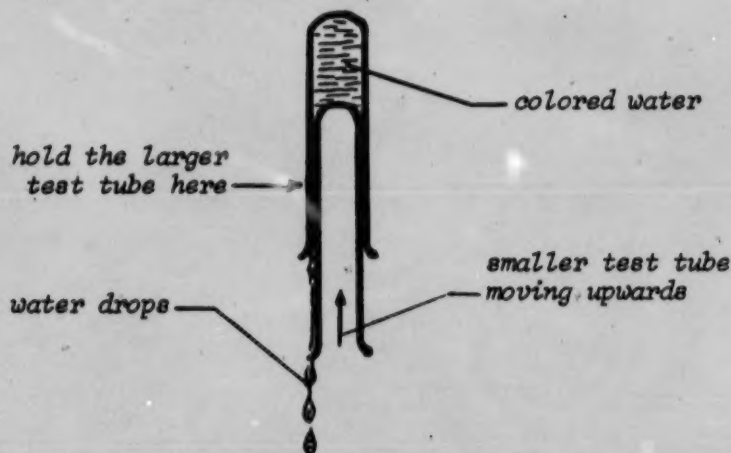
If there were no air pressure in the atmosphere, we would not be able to suck liquids through a straw. If the mouth of an astronaut was connected to a straw through his space suit to an open cup with liquid on the moon surface, he would not be able to drink the liquid by sucking through the straw, because there is no pressure on the liquid surface that will push it up the straw.

AIR

EXERTING PRESSURE

1.9. THE UPWARDS FALLING TEST TUBE

- Materials:
1. Two test tubes, one just fitting into the other
 2. A little colored water.

Procedure:

1. Fill the larger test tube half way with colored water.
2. Let the smaller test tube float on the water; push it a little further in so the water will overflow.
3. Now invert both test tubes over a small container to catch the dripping water and hold only the larger test tube (you may need to push the smaller tube up to start the motion).

Questions:

1. What happened to the volume of the water after inverting?
2. What made the smaller test tube move upwards?
3. What would be the total force pushing the test tube upwards?
4. Would this 'falling upwards' also succeed with a much smaller test tube floating on the water of a much larger test tube and then inverting it? Why? Why not?

Explanation:

The smaller test tube has to be pushed a little further into the larger one till the water overflows, so that no air will be left between the two test tubes. After inverting the set of test tubes, the water is dripping out *decreasing the volume of the water*. Since there is no air above the smaller tube, the outside air pressure is pushing it up. The total force upwards is 1 kg per cm^2 . For a test tube with about 1.2 cm diameter this upward force is about 1 kg . This event of 'falling up' will not succeed with two test tubes that have a larger difference in diameter, because the air will be able to replace the dripping water and thus equalize the pressure above and under the smaller test tube.

Other thought questions would be:

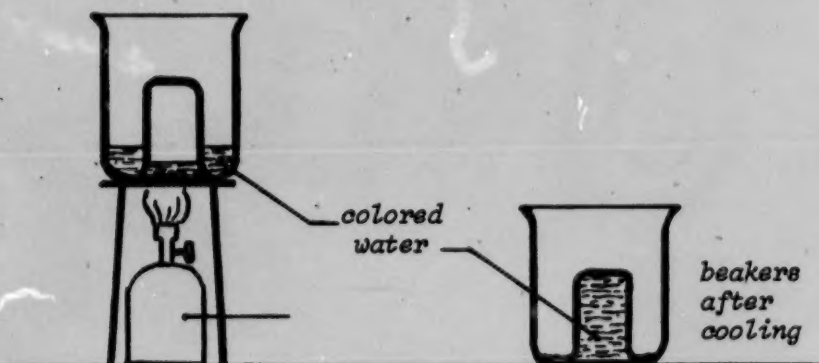
- Would this event work on the surface of the moon?
- Would this event work in a pressurized satellite around the earth?

AIR

EXERTING PRESSURE

1.10. THE MYSTERIOUSLY RISING WATER (I)

- Materials:
1. One small beaker (100 ml) & one large beaker (400 ml)
 2. One hot plate or burner and stand
 3. Boiling chips and food coloring

Procedure:

1. Put about 110 ml of water in the large beaker, a few drops of food coloring and a few boiling chips.
2. Heat this beaker and the water to a boil, while the small beaker is placed upside down inside the larger beaker.
3. Let the water boil for at least one full minute, taking care that the small beaker does not tip over.
4. Take the two beakers off the fire and let them cool to room temperature. Observe the water level in the small beaker.

Questions:

1. What is inside the inverted small beaker before the heating?
2. What happens to the water when we boil it?
3. Why does the small beaker keep bobbing up and down?
4. What do the bubbles consist of?
5. Why does the water level rise in the small beaker?
6. What would happen if after the heating, we put a few drops of cold water on the small inverted beaker?

Explanation:

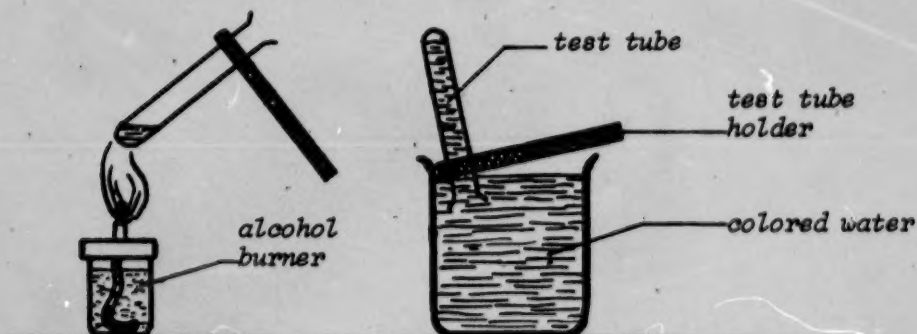
By boiling the water, it is changing from the liquid state into the gaseous or vapor state. This water vapor is also formed under the inverted beaker and it replaces the air under this beaker. The longer we let the water boil, the more air will be replaced by water vapor. The cooling process makes this water vapor condense and turn back into water, thus reducing the pressure inside the small beaker. The water is therefore pushed up inside the inverted beaker by the higher atmospheric pressure. By letting a few drops of cold water drip on the inverted beaker, the cooling process is speeded up and also the rising of the water.

AIR

EXERTING PRESSURE

1.11. THE MYSTERIOUSLY RISING WATER (II)

- Materials:**
1. One test tube & test tube holder
 2. One large beaker (400 ml) or other water container
 3. One Bunsen or alcohol burner & food coloring

**Procedure:**

1. Fill the large beaker with cold water and color.
2. Put a little water in the test tube (about 3 ml) and boil it (A).
3. After the water has been boiling vigorously for about 10 seconds, invert this test tube immediately in the colored water (making sure that the test tube mouth stays under water; see Sketch B).

Questions:

1. What is in the test tube besides the water before heating?
2. What is in the test tube during the heating?
3. What happens during inverting of the test tube in the colored water?
4. What does water do when it is boiled?
5. What does water vapor do when it is cooled?
6. How did the temperature of the test tube change when it was inverted?
7. Why did the colored water rise in the inverted test tube?

Explanation:

Before the heating, the test tube was filled with a little water and the rest was air. Water vapor was produced by boiling the water and this water vapor pushed out the air in the test tube (vigorous boiling of the water). After inverting the test tube in the colored cool water, the hot water from the test tube poured out into the large container, the test tube slowly cooled off, causing the water vapor to condense. This decreases the pressure inside the test tube and thus the water is pushed up the tube by the existing atmospheric air pressure.

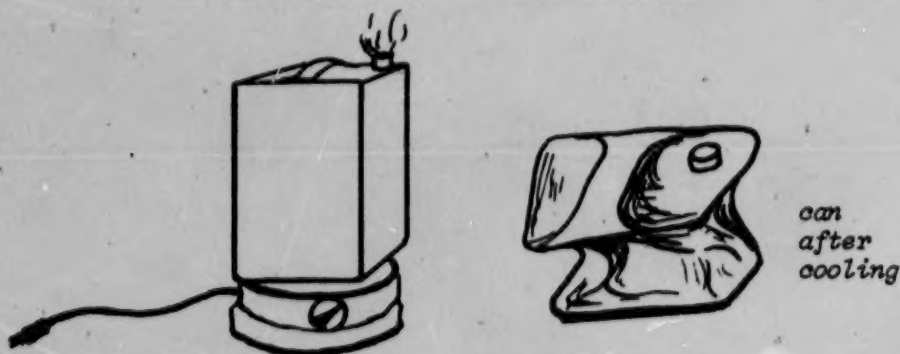
Other very similar events are: *The Mysteriously Rising Water (I)* and *The Fountain in a Flask*. We encounter this kind of an event in daily life sometimes when, after boiling water or soup in a pan with a well fitting top, cooling the pan afterwards and trying to open the cover, only to find the cover to be sticking to the pan.

AIR

EXERTING PRESSURE

1.12. THE COLLAPSING CAN

- Materials:
1. One empty gallon (or 4-5 liter) can, or any other tin can that can be closed off air-tight.
 2. A hot plate or burner and tripod

Procedure:

1. Put about 20 ml of water in the can (just enough to cover the bottom) and heat it over the hot plate or burner.
2. Let the water boil vigorously for about 2 minutes (vapors should come out of the can).
3. Take the can with the boiling water off the heat (don't burn your fingers!) and immediately close off with the cap very tightly.
4. Let it stand upright on the table and cool off to room temperature, or for faster results: cool off with wet towel.

Questions:

1. What was in the can besides the water?
2. What happens when water is boiled?
3. What will the air in the can do when much water vapor is formed?
4. What would happen if we did not close the can very tightly?
5. What is the total force that is working on the outside of the can?

Explanation:

Before heating, the can was filled with water and air. By boiling the water, it changed states, from liquid to gaseous state (water vapor). The water vapor or steam pushed the air that was inside, out of the can. In closing off the can with an air-tight cap, we are actually trapping the air out of the can: we are preventing it from going back into the can. The cooling *condenses* the water vapor back to water. All the vapor which took up the interior space of the can before, is now turned into a few drops of water, which take up much less space. This causes the pressure to drop and the atmospheric pressure is therefore pushing on the can and crushing it.

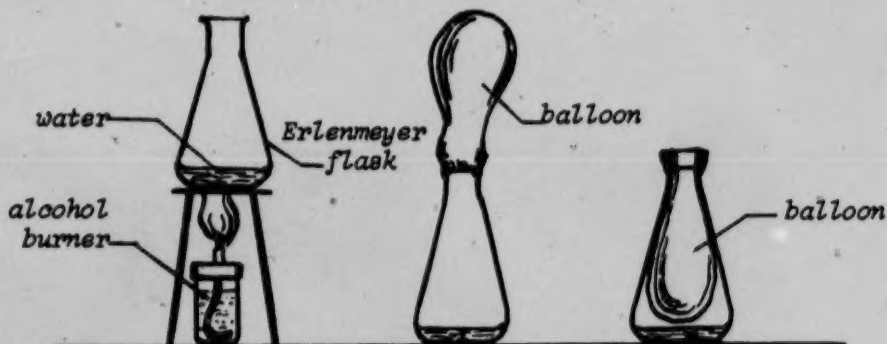
The total force working on the outside of the can is the total of the can's surface area in cm^2 multiplied by 1 kg.

AIR

EXERTING PRESSURE

1.13. THE BALLOON IN A FLASK

- Materials:
1. An Erlenmeyer flask (150-200 ml)
 2. A round balloon with a large mouth (uninflated)
 3. A hot plate or burner and stand

Procedure:

1. Put a little water (about 20 ml) in the flask and heat it to a boil (use a few boiling chips).
2. Let the water boil vigorously for at least one full minute.
3. Take the flask off the fire and immediately place the balloon with the mouth over the flask's mouth.
4. Let cool slowly at room temperature (the balloon will be sucked inside out into the flask).

Questions:

1. What is in the flask besides the water?
2. What is water doing if we boil it?
3. What is the steam doing to the air in the flask?
4. Why did the balloon go inside the flask?
5. Why did the balloon continue to expand inside the flask?

Explanation:

By boiling the water in the flask, it was changed from the liquid state into the vapor state. Water vapor or steam is formed and this pushes the air that was originally present in the flask, out of the flask. The longer we let the water boil, the less air will be left in the flask. After the flask is closed off with the balloon, the air cannot get back into the flask. The cooling of the flask will slowly *condense* the water vapor and thus create a *partial vacuum* in the flask. This will cause the sucking in of the balloon and the *atmospheric air pressure* will further blow up the balloon inside the flask.

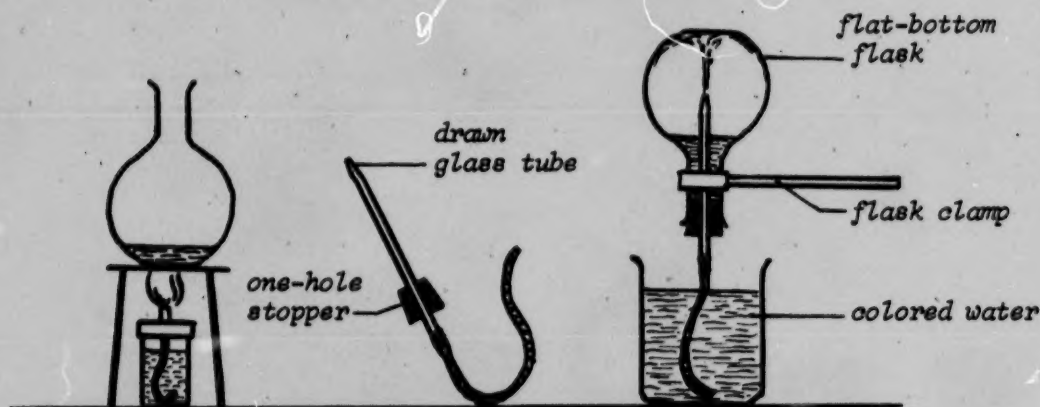
During the cooling of the flask and the sucking in of the balloon, care has to be taken that the balloon's mouth is not pinched closed (this will prevent the whole balloon from getting into the flask; only part will go in and probably burst).

AIR

EXERTING PRESSURE

1.14. FOUNTAIN IN A FLASK

- Materials:**
1. One round- or flat-bottomed flask (400 ml) & holder
 2. A glass tube drawn at one end in a 1-hole stopper
 3. A beaker (500 ml), rubber tubing, boiling chips
 4. A hot plate or burner and stand



Procedure: Sketch A

Sketch B

Sketch C

1. Put about 30 ml of water in the flask and heat it over the fire.
2. Let it boil for at least one full minute (see Sketch A).
3. Get ready with the glass tube, stopper and rubber tubing to close off the flask (see Sketch B).
4. Hold the flask by the flask holder, take it off the fire, and insert the stopper with the drawn tube on the flask.
5. Immediately invert the stoppered flask and dip the end of the rubber tubing into the colored water in the beaker (see Sketch C).

Questions:

1. Why is water needed in the flask?
2. Would the water also be drawn up if the flask was heated without any water in it?
3. What caused the water to go up the tube?
4. Why did the water go up the tube so slowly in the beginning?
And why did it suddenly speed up after the water hit the flask?

Explanation:

Boiling the water produced water vapor in the flask and this caused the air to be pushed out. By closing the flask off with the stopper, the air was trapped out. The cooling of the flask after inverting caused the water vapor to condense slowly and to contract, with a decrease of pressure as a result. The water is therefore sucked up the tube slowly. As soon as the cool water hits the bottom of the flask, this latter cools off much faster and the water vapor condenses much faster, creating a sudden partial vacuum, thus sucking up the water vigorously. (Bromthymol Blue in the beaker and acid in the flask gives color change).

AIR

EXERTING PRESSURE

1.15. THE STICKING CUP OF WATER

- Materials:
1. A Petrie dish (or other shallow dish with smooth rim)
 2. A smooth surface, ceiling, or under-side of a table

Procedure:

1. Fill the Petrie dish brim-full with water.
2. Bring the dish to the smooth surface: push it against the surface making sure that there are no air bubbles left in it.
3. At this point make sure that the dish will stick to the surface, then ask a student to hold it up or do as if you need to get something and have to leave the dish.
4. Give the student permission to let go of the dish or say: "Maybe I can let go of the dish" (if holding it yourself).

Questions:

1. Why do we need a smooth surface?
2. Why does the dish stick to the surface?
3. How much force is holding the dish up?
4. How heavy a dish can we stick to the surface?
5. How long will the dish keep sticking to the surface?

Explanation:

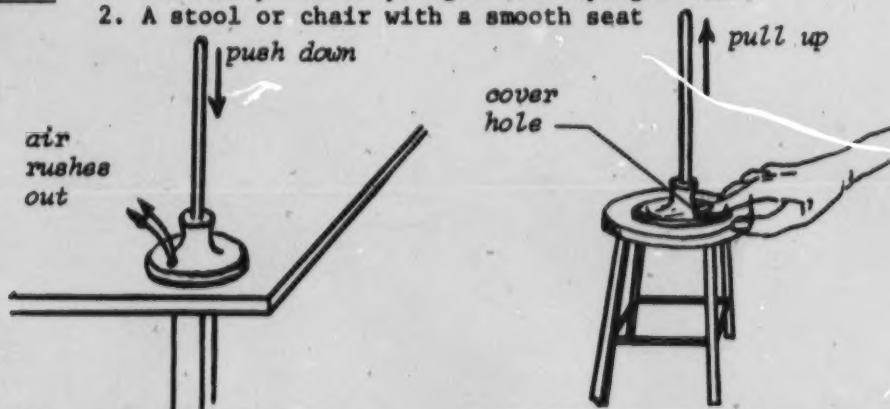
By filling the dish completely full with water, there is no air left and thus there is no air pressure working down on the dish. The only force working down on the dish is gravity and thus the weight of the dish plus the water. The force holding the dish against the surface is equal to the air pressure of 1 kg per cm^2 of dish surface area. A dish with a 3 cm radius will have a force of about 27 kg holding it up minus the weight of the water and the dish itself. Once the dish is sticking to the surface, it will stay up for quite a long time until some water evaporates and air seeps into the dish.

The water, in this case, acted as a seal preventing the air to come into the dish. An application of this principle is when we wet suction cups with water to make them stick better to smooth surfaces.

AIR

OCCUPYING SPACE
EXERTING PRESSURE1.16. THE BIONIC FINGER (I)

- Materials:
1. One heavy rubber plunger (to unplug a sink)
 2. A stool or chair with a smooth seat

Procedure:

1. Make a small hole in the plunger with a scissor's point.
2. Show the students the plunger and ask: "What is under the plunger when I place it on the table?" (anticipated answer: 'nothing').
3. Ask one of the students to come up and put his/her cheek close to the hole in the plunger.
4. Push the plunger in: air rushes out and blows against the cheek! **AIR OCCUPIES SPACE!** (see Sketch A).
5. Show the students the plunger on top of a stool.
6. Tell them that you possess a bionic finger and that you can hold down the plunger against the stool with one finger.
7. Push down on the plunger and hold it down with one finger covering the hole (a wet finger will work better), and ask a student to come up and pull the plunger up (See Sketch B).
The whole stool will stick to the plunger and be lifted!

Questions:

1. What was under the plunger?
2. What was helping my finger to keep the plunger down?
3. How much force is pressing down on the plunger?
4. How heavy can the stool be and still be lifted up?

Explanation:

There was air under the plunger and it rushed out when it was pushed in. When holding the plunger down with one finger, the hole was covered and this prevented the air from coming back in under the plunger, causing a lower pressure under it. A moist finger works better to plug the hole, because the water acts as a seal.

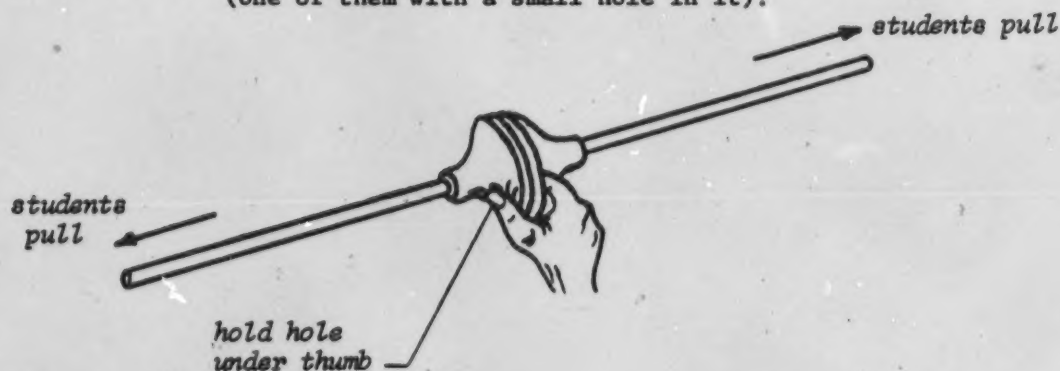
The force holding down the plunger is equal to the surface area of the plunger multiplied by 1 kg (about 75 kg for a plunger with a 10 cm diameter).

AIR

EXERTING PRESSURE

1.17. THE BIONIC FINGERS (II)

Materials: 1. Two heavy rubber plungers (to unplug a sink)
(one of them with a small hole in it).

Procedure:

1. Ask two students to come up and push the two plungers against each other.
2. Ask them now to pull them apart (can be easily done).
3. Tell the students now that you have *bionic fingers* to keep the two plungers together.
4. Let the students push the two plungers together again and this time hold the plungers with thumb and forefinger, making sure that you cover the hole with your thumb (a wet finger works better).
5. Now let the students try to pull the plungers apart (most likely the wooden handle will come off first!).

Questions:

1. Why was it so easy to pull the plungers apart before I held them?
2. What did actually hold the plungers together?
3. Did I have to hold the plungers in a special way?
4. How much force was keeping the two plungers together?
5. Would larger or smaller plungers stick together better?

Explanation:

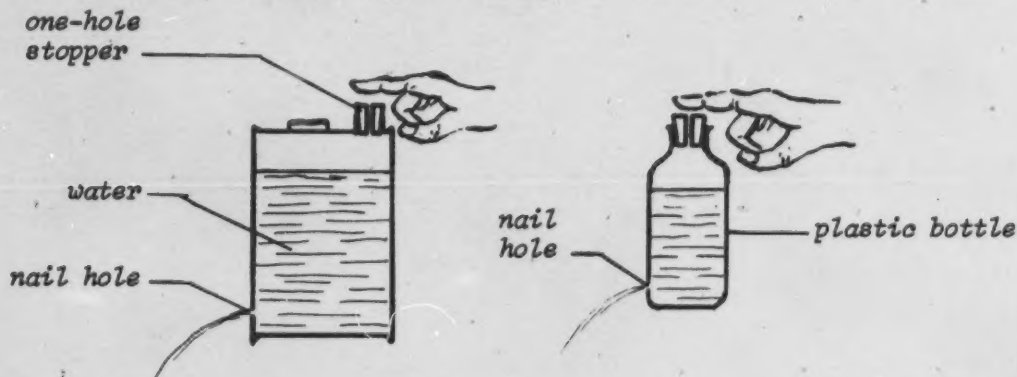
The plungers were quite easy to separate before holding them together because there was a hole in one of them, allowing the air to come inside between the two plungers. By covering the hole, the air was prevented to come in (water on the finger acts as a seal) and when the students tried to pull them apart, the volume increased between the plungers, thus decreasing the pressure. It was again the atmospheric air pressure that was holding the two plungers together. The total force that was holding them together can be calculated from the total surface area of the two circles multiplied by 1 kg (about 150 kg for plungers with a 10 cm diameter). A similar experiment was done with large steel half-spheres and horses pulling on each side: Maagdenburg spheres.

AIR

EXERTING PRESSURE

1.18. STOP THE LEAK

- Materials:**
1. An empty can or plastic bottle.
 2. A one-hole stopper fitting the neck of the can or bottle.

Procedure:

1. Punch a hole in the side near the bottom of the can or bottle with a small nail.
2. Fill the can or bottle with water and show the leaking container.
3. Ask: "How can I stop the leak without wetting my finger?"
4. Put the one-hole stopper on the can or bottle and cover the hole with one finger: the leak is stopped!
5. Release your finger from the stopper: leak will start again.

Questions:

1. Why did the water stop flowing out of the can?
2. How could we stop the leak without the one-hole stopper?
3. Does the water stop flowing immediately after the hole is covered?
4. How does the air pressure inside the can compare with the atmospheric air pressure after the water stops flowing?
5. What is it that we prevent from entering the can by covering the hole?

Explanation:

The water does not stop flowing immediately after covering the stopper, but it still keeps dripping out of the can for a while. This increases the volume of the air pocket above the water. The amount of air stays the same because air is prevented from coming into the hole in the stopper. The increase in volume causes a decrease in pressure (Boyle's Law). The outside atmospheric air pressure pushes against the water and prevents it from flowing out.

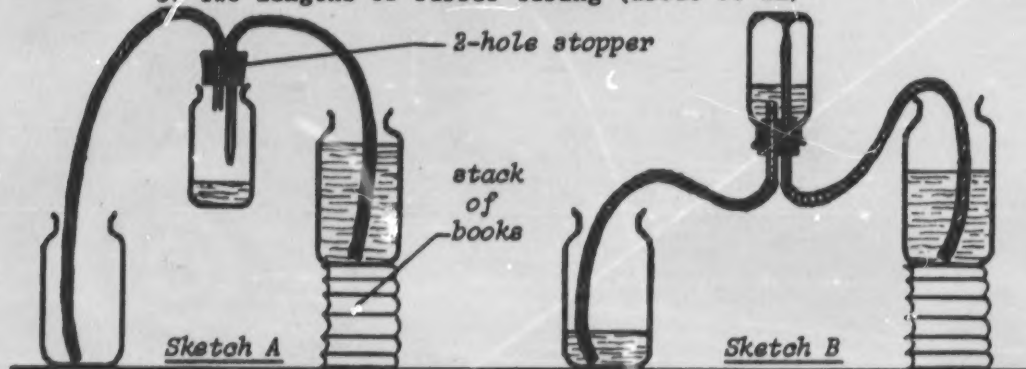
This is why we always punch two holes in a can of evaporated milk in order to pour the milk out. Also on a gallon frying-oil can, it usually is recommended to punch a hole in a corner opposite the pouring spout. This hole will allow air to enter the can while oil pours out. It will promote a smooth flowing of oil out of the can.

AIR

EXERTING PRESSURE

1.19. THE PERPETUAL FOUNTAIN?

- Materials:
1. One medium sized jar and two large bottles.
 2. A 2-hole stopper fitting the jar, 2 glass tubes (the longer one drawn to a point at one end).
 3. Two lengths of rubber tubing (about 30 cm)

Procedure:

1. Push the two pieces of glass tubing through the 2-hole stopper such that the one with the point extends farther than the other (see Sketch).
2. Connect the two lengths of rubber tubing to the glass tubes.
3. Fill one of the two large bottles full with cold water and set up the flask and the two bottles as shown in Sketch A (Hold the jar).
4. Pour about 100 ml of water in the jar and insert the stopper tightly.
5. Invert this jar, making sure that the two rubber tubes stay in the two bottles (the end of the tube in the bottle with water should stay under water at all times).

Questions:

1. What was the first thing that happened after inverting the jar?
2. What happened to the volume of the air pocket above the water in the jar as the water poured in the empty bottle?
3. Why was the water drawn up into the jar?
4. Why does the water-filled bottle have to stand higher than the other?
5. How can we make the fountain flow harder or slower?

Explanation:

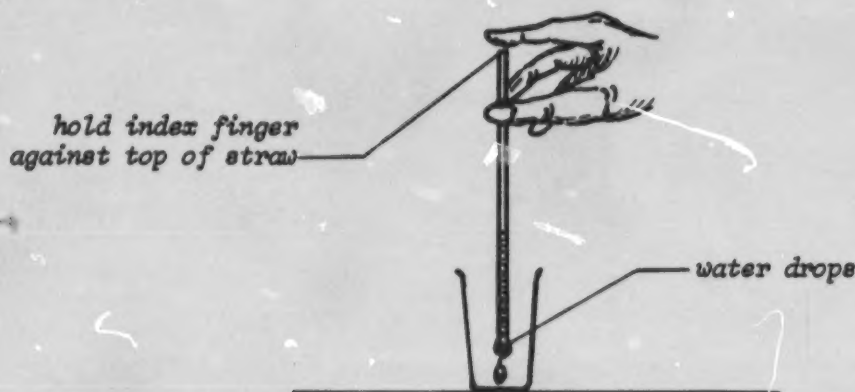
The water in the jar was needed to 'prime' the siphoning action. Immediately after inverting the jar, the water ran down and out into the empty bottle. This caused an increase in volume of the air pocket above the water in the jar, thus decreasing the pressure. This lower pressure caused the sucking up of the water from the water-filled bottle. In other words, the atmospheric air pressure is pushing the water up into the jar. The larger the difference in height of the water levels in the two bottles the stronger the flow of water. As soon as the water levels are the same height in both bottles, the water flow will stop. This is the same principle of the siphon.

AIR

EXERTING PRESSURE

1.20. TRANSFER WATER WITH A STRAW

- Materials:**
1. One drinking straw for each group of three students.
 2. Two small cups for each group of three students.

**Procedure:**

1. Divide the class in groups of three students.
2. Provide each group with one straw and two cups.
3. Let one student hold a water-filled cup, another an empty cup and the third transfer the water from one into the other cup.
4. Ask the students how they can do this without tilting the cups.
5. Demonstrate how the water can be held in the straw:
 - dip the straw vertically in the water-filled cup;
 - hold forefinger against top end of straw and lift;
 - move straw with the water in it over the empty cup and release finger: water drips out!

Questions:

1. How can we transfer the water without tilting the cups?
2. How can we hold water in the straw without sucking through it?
3. What holds the water in the straw when your forefinger is closing off the top end of the straw?
4. What happens if we try to hold the water in the straw and not close the top end of the straw tightly?
5. What is prevented from coming in the straw at the end where our finger is pressing?
6. What is holding the water back if we close the top end of the straw with our finger before immersing it in the water?

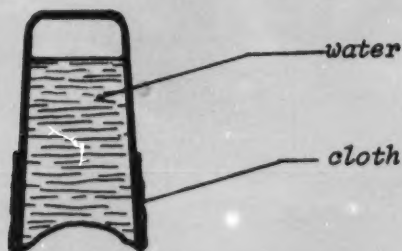
Explanation:

By closing off the top end of the straw with our forefinger, we prevent the air from coming in. Some water will drip out of the lower end of the straw, enlarging the volume of the air pocket above the water and thus creating a lower pressure inside the straw. The outside atmospheric pressure is holding the water up in the straw. When the finger is released, air is allowed to enter and the pressure is equalized.

AIR

EXERTING PRESSURE
COHESIVE FORCES1.21. THE WATERTIGHT CLOTH

- Materials:
1. A drinking glass
 2. A piece of cheese cloth (or any other thin cloth) large enough to cover the mouth of the glass.

Procedure:

1. Fill the glass half way or full with water.
2. Wet the cloth under the tap and show students that water will flow easily through the cloth.
3. Place the cloth now over the mouth of the glass and push the fringes against the side of the glass.
4. Hold the fringes with one hand against the glass; with the other hand hold the bottom part of the glass without holding the cloth and invert.
5. Let go of the first hand: cloth and water will stay up in the glass!

Questions:

1. Why would this not work with a dry cloth?
2. Why does the wet cloth cling to the sides of the glass?
3. Why does some water flow out of the glass in the beginning?
4. Why does the water stop flowing out?
5. What is keeping the water and the cloth up?
6. Can we hold the glass slanted or sideways without letting the water flow out?
7. What shape does the cloth take when we hold the glass vertically upside down?

Explanation:

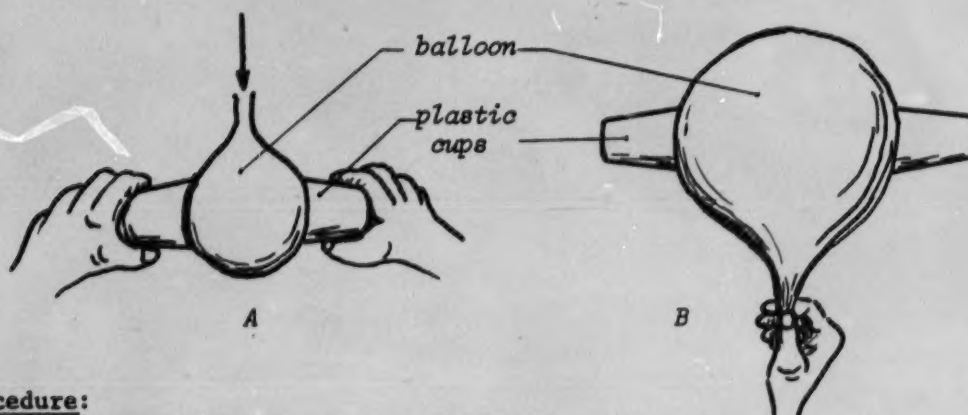
The cloth needed to be wet with water so that it could adhere to the sides of the glass (adhesive forces between water and cloth, and water and glass). During the process of inverting, some water poured out because the cloth is porous, but this caused an increase of the air pocket volume above the water, which in turn reduced the pressure inside the glass. This demonstration can also be used to show the cohesive forces between the water molecules, as a film of water molecules is formed in the little pores of the cloth.

AIR

EXERTING PRESSURE

1.22. THE CUPS AND THE BALLOON

- Materials:**
1. An uninflated round balloon
 2. Two small plastic or glass cups (with a smooth rim).

**Procedure:**

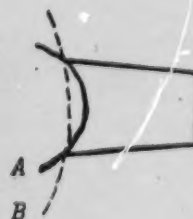
1. Blow up the balloon about one third way.
2. Tell the students that you will hold the two cups against the sides of the balloon and blow it further up.
3. Hold one cup in each hand, hold the cups against opposite sides of the balloon (while the balloon is in the mouth) and blow further (until about twice the size).
4. Let go of the two cups (they will stick to the balloon, if not, moisten the cup rims) and hold the balloon in one hand by the mouth.
5. Show the students that the cups are not glued to the balloon by releasing the air slowly out of the balloon (the cups will fall off as the balloon gets smaller).

Questions:

1. Why did the cups stick to the balloon?
2. Did the air pressure in the balloon have anything to do with it?
3. How does the volume of the cups change from stage A to stage B?
4. What does the pressure inside the cups have to be to stick to the balloon, compared to the atmospheric pressure (in stage B)?
5. How much larger does the balloon have to be in stage B compared to stage A for the cups to stick to it?

Explanation:

Because of the increase in curvature or actually a flattening of it from A to B, the volume in the cups increased, thus causing the pressure to decrease. The air pressure inside the balloon had nothing to do with the sticking of the cups to the balloon.

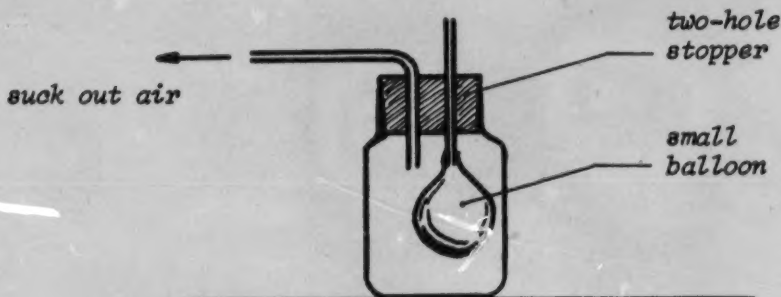


AIR

EXERTING PRESSURE

1.23. INFLATE A BALLOON BY SUCKING

- Materials:
1. An empty glass jar & a fitting 2-hole stopper
 2. Two lengths of glass tubing (one with a 90° bend)
 3. A small balloon & tape or rubber band

Procedure:

1. Insert the glass tubing into the stopper and tie or tape the small balloon to the end of the straight tube.
2. Place the stopper with the tubing and the balloon over the jar, insert tightly, and set up the equipment as shown in the sketch above.
3. Suck through the bent glass tube until the balloon is inflated and close off the end of the bent tube with your finger (prevent the air from getting back into the jar).
4. Ask the students all the questions.

Questions:

1. What was I doing to inflate the balloon?
2. How does the pressure inside the jar compare to the pressure outside the jar during inflation of the balloon?
3. Why doesn't the balloon deflate? (finger over end of bent tube).
4. How else can the balloon be inflated?
5. What would happen if I blew through the bent tube?
6. How does the pressure inside the jar compare to that of outside during inflation of the balloon by blowing through the straight tube?

Explanation:

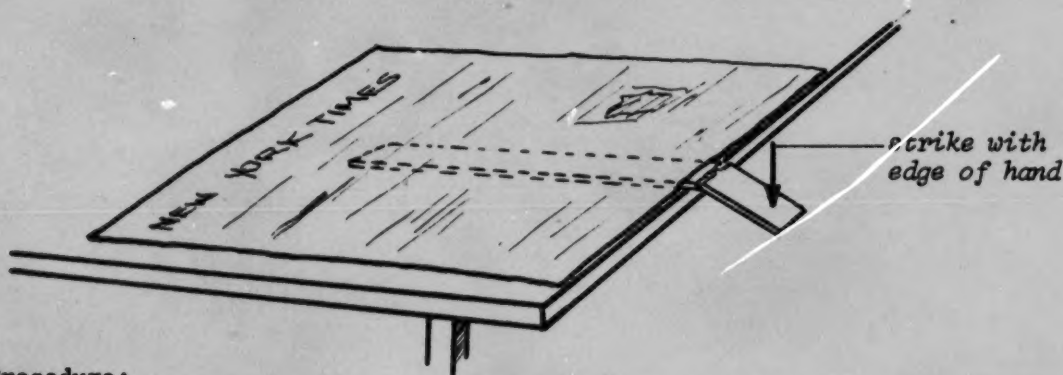
By sucking through the bent tube, the pressure inside the jar is decreased and the atmospheric air pressure is inflating the balloon. By placing the finger over the end of the bent tube (after inflating the balloon), the air is prevented from reentering the jar. A lower pressure inside the jar (outside the balloon) is now maintained, which causes the balloon to stay inflated even with an open mouth. Another way to inflate the balloon is to blow through the straight tube, and by putting a finger over the bent tube it can be kept inflated. This way, during inflation the pressure inside the jar is higher than the atmospheric pressure.

AIR

EXERTING PRESSURE

1.24. THE HEAVY NEWSPAPER

- Materials:
1. One or two full sheets of an ordinary newspaper.
 2. A stick of pine wood (.3x3x75 cm or $\frac{1}{4}$ "x1"x2')
(a piece of wood paneling or old ruler is excellent)

Procedure:

1. Place the stick on a table with a smooth surface and let it protrude over the edge about 8 cm.
2. Ask: "What will happen if I hit this protruding end of the stick?" (anticipated answer: 'stick will fly up').
3. Strike it and let the students catch the flying stick.
4. Place the stick back on the table like in point 1, and cover it with the newspaper flush with the edge of the table.
5. Ask: "What do you think will happen now if I hit it again?" (anticipated answer: 'the paper will fly up' or 'paper will tear').
6. Smoothen down the paper with your left hand and strike the protruding end of the stick with your right hand (a sudden sharp blow with the edge of the palm); stick breaks!
7. By pulling the stick out another 8 cm after breaking, the cycle of smoothening the paper and breaking (point 6) may be repeated.

Questions:

1. What did I do with my left hand?
2. Why was it necessary to smoothen the paper before hitting?
3. What would happen if the protruding end of the stick was slowly pushed down?
4. How much weight was actually holding the stick down?

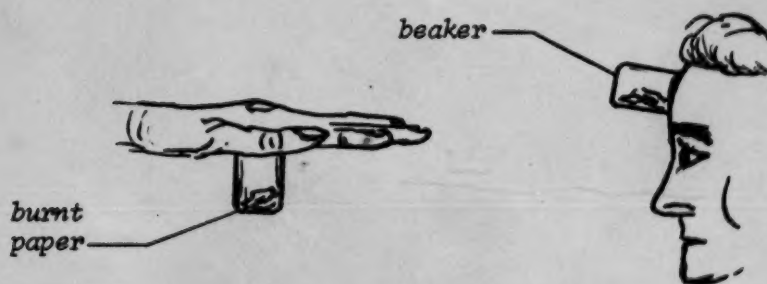
Explanation:

By smoothening the paper down, there was almost no air under it, but a whole column of air exists above the paper, pushing down on the paper with the atmospheric pressure. This is about 1 kg/cm^2 (14.6 or rounded 15 lbs per sq.in.). The total weight or force pushing down on a 60 x 80 cm or 20" x 30" paper is roughly: $60 \times 80 \times 1 \text{ kg} = 4800 \text{ kg}$, or $20 \times 30 \times 15 \text{ lbs} = 9000 \text{ lbs}$, which is close to the weight of two large stationwagons! It is therefore impossible to lift it with the thin stick!

AIR

EXPANSION BY HEAT
EXERTING PRESSURE1.25. THE MAGIC BEAKER

- Materials:
1. A small jar (50 ml) or small wine glass.
 2. A piece of paper and matches.

Procedure:

1. Show that the jar or wine glass is empty by inverting it.
2. Crumple a small piece of paper.
3. Strike a match and start burning the paper.
4. Place the burning paper in the jar or wine glass and immediately press the jar against your forehead or against the palm of your hand (keep pressing until the fire is out or until you feel a suction).
5. When you feel a suction inside the jar, slowly let go of it (it will stay stuck against your forehead or palm).

Questions:

1. What was inside the jar or glass before burning the paper?
2. Why did the flame inside the jar go out?
3. What does the heat of the flame do to the air inside the jar?
4. What was left inside the jar after the flame went out?
5. What made the jar or glass stick to the forehead or palm?

Explanation:

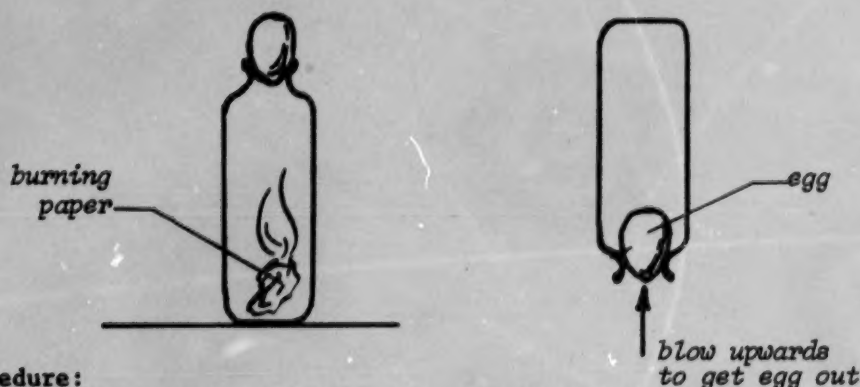
Although you showed the pupils that there was 'nothing' in the jar by holding it upside down, there was naturally air in it. By placing the burning piece of paper in the jar, the air inside the jar was heated and expanded. The expansion made the air rush out of the jar and when pressed against the forehead or palm of the hand, the jar was closed off from the outside air. This caused the flame to go out, because there was no more oxygen to feed the burning process. The extinguishing of the flame caused the air inside the jar to cool off and thus to contract. The pressure inside the jar was therefore getting smaller than the atmospheric pressure outside the beaker, and this higher air pressure kept the jar against the forehead or palm. In other words, a partial vacuum was created inside the jar, which kept the jar stuck against the skin surface.

Warning: The partial vacuum will leave a red spot on the skin, which will disappear in a few hours or longer, depending on how long the beaker has been left against the skin!

AIR

EXPANSION BY HEAT
EXERTING PRESSURE1.26. THE EGG AND THE MILK BOTTLE

- Materials:
1. One hard-boiled egg.
 2. One empty glass milk bottle.

Procedure:

1. Peel the shell off from the hard-boiled egg and place the egg on the mouth of the milk bottle.
2. Ask: "What will happen if I put a burning piece of paper in the bottle and place the egg back on the bottle?" (anticipated answer: 'egg might jump off', 'fire goes out', 'the bottom of the egg will get black', 'the bottle might crack', etc.)
3. Burn a small piece of paper, lift the egg up, put the burning piece of paper in the bottle and place the egg immediately back on the bottle's mouth (egg will be sucked into the bottle).
4. Ask question number 4.
5. To get the egg out of the bottle whole: invert the bottle and let the egg fall in the bottle neck, blow a short spurt of air up into the inverted bottle and catch the falling egg.

Questions:

1. Why did the egg get pushed inside the bottle?
2. What did the burning paper do to the air inside the bottle?
3. What did the egg do before it went into the bottle? (Observe!)
4. How can we get the egg out of the bottle without cutting it up?
5. Is there another way to get the egg out whole?

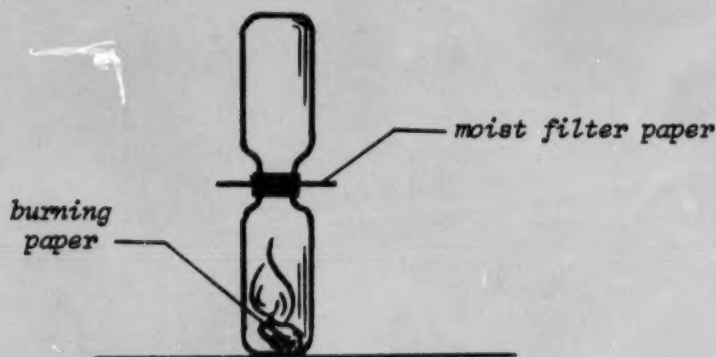
Explanation:

The burning paper is heating the air in the bottle and expanding it, and this is why the egg was vibrating before it was sucked into the bottle. Some of the air slipped under the egg out of the bottle and thus there was less air pressure in the bottle. An added cause for decreasing the pressure inside the bottle is, that the burning of the paper took away the oxygen of the remaining air, turning it into CO_2 and water vapor. The latter condensed against the cold bottle. Another way to get the egg out is, to warm the bottle while the egg sits in the bottle neck.

AIR

EXPANSION BY HEAT
EXERTING PRESSURE1.27. THE TWO BOTTLES IN LOVE

- Materials:
1. Two identical bottles with thick smooth rims (medicine bottle)
 2. A piece of filter paper or blotting paper.

Procedure:

1. Soak the filter paper in water and place it over one of the bottles.
2. Twist a small piece of paper and make sure that it will fit through the mouth of the other bottle.
3. Burn this twisted piece of paper, put it in the open bottle and immediately cover this bottle with the filter-paper-covered bottle.
4. Press the top bottle for a few seconds longer on the lower one (until the flame of the burning paper is completely extinguished).
5. Now lift the two bottles up by holding on only to the top bottle.
6. Hold both bottles, invert the set, and let go of the lower bottle.

Questions:

1. What did the burning paper do to the air in the bottle?
2. Why did the filter paper have to be soaked in water?
3. Why did the two bottles stick to each other?
4. Would the bottles stick to each other without the filter paper? Why?
5. How long will the two bottles stick to each other?

Explanation:

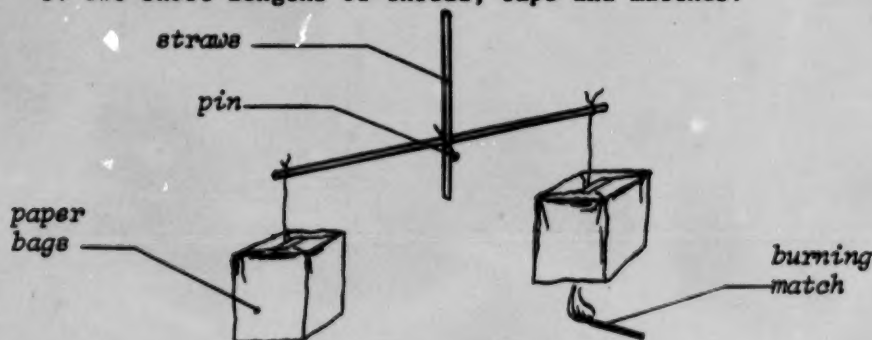
The burning paper heated up the air in the open bottle, which caused the air to expand. Thus some of the air in this bottle escaped. By covering this bottle immediately with the other bottle, the escaped air was trapped outside. The air pressure outside the bottles is keeping the set pressed together. The moist filter paper functions as a seal between the two bottles making them almost airtight. Without this filter paper, the air would seep between the two bottles and the trick will not work. The two bottles will stick together as long as the pressure inside is lower than the atmospheric pressure. Slowly air will seep in through the filter paper and as soon as the air pressures inside and outside the bottles are equalized, the bottles come apart.

AIR

EXPANSION BY HEAT

1.28. THE INVERTED PAPER BAG BALANCE

- Materials:**
1. Two small identical paper bags.
 2. Two drinking straws and a pin.
 3. Two short lengths of thread, tape and matches.

**Procedure:**

1. Open the two small paper bags, invert, and attach the thread to the center of the bottom with a piece of tape.
2. Hang the two bags upside down on the ends of one of the straws, and balance this on a pin attached to the other straw as shown in the sketch (make sure that the straws move freely around the pin).
3. Let one of the students hold the vertical straw, strike a match and hold the flame under one of the bags (be careful not to set the bag on fire).
4. This bag moves up. Take the flame away and the equilibrium is restored (both bags will be in balance again).
5. Hold a flame under the other bag and this side will now move up.

Questions:

1. What is in the bags?
2. What is air doing if it is heated?
3. Why did the heated bag move up?
4. What happened after the flame was taken away from under the bag?
5. In which direction does heated air move?

Explanation:

The flame under the bag heats up the air in the bag and expands it. This leaves less and lighter air in the bag. This lighter air pushes under against the bag and the bag moves up. When we take the flame away, the warm air cools down and slowly the balance of the two bags is restored.

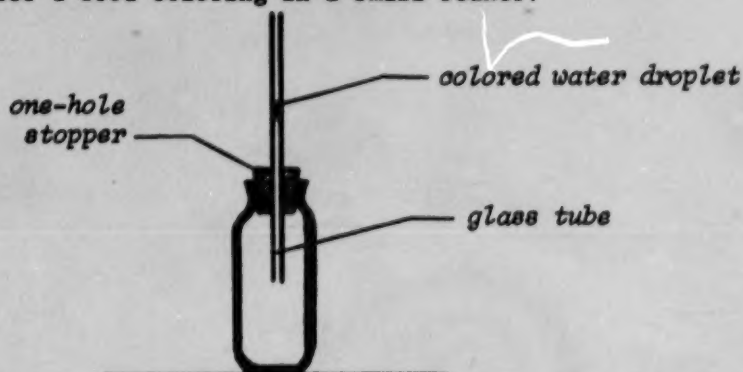
This principle of making air lighter by heating is applied in *hot air balloons*. Air inside the balloon is heated, it expands and becomes lighter and the balloon is pushed up by the lighter air (compared to the surrounding atmospheric air). The larger the balloon, the larger the force upward and thus the more weight it can lift.

AIR

EXPANSION BY HEAT

1.29. SQUEEZE THE GLASS BOTTLE?

- Materials:**
1. An empty glass bottle.
 2. Glass tubing (about 30 cm) in a fitting 1-hole stopper.
 3. Water & food coloring in a small beaker.

**Procedure:**

1. Color a few milliliters of water with food coloring in the beaker.
2. Dip the end of the glass tubing in the colored water and close the other end off with a finger. Take the tube out of the water, hold the tube horizontal and let the waterdrop ride in the tube until close to the stopper. (close off the end again with the finger)
3. Place the stopper in the bottle neck and insert tightly (waterdrop will move up some).
4. Mark off the position of the waterdrop with a grease pencil, masking tape, or rubber band.
5. Hold bottle in both hands: what happens to the waterdrop?
6. Let the bottle stand on the table: what happens to the waterdrop?

Questions:

1. What is in the bottle?
2. Why does the waterdrop not slide down into the bottle?
3. Why does the waterdrop move up when inserting the stopper?
4. What made the waterdrop move up when the bottle was held?
5. How can we get the waterdrop to move down the tube?

Explanation:

The 'empty' bottle is of course filled with air. In closing off the bottle with the stopper and tube, the waterdrop was pushed upwards by the air. It is because of the presence of air inside the bottle that the waterdrop in the tube cannot slide down by itself. It is actually held up in the tube by the air.

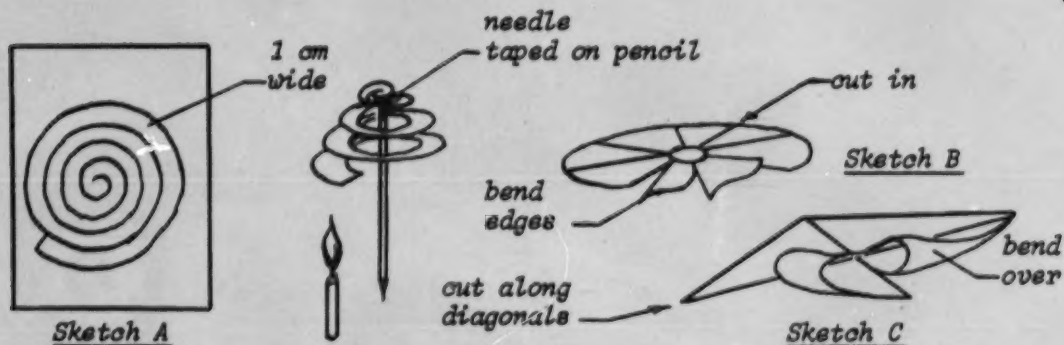
By holding the bottle in our hands, our body heat is warming up the bottle, which in turn warms the air. This air expands and pushes the waterdrop up the tube. By cooling the bottle with cool water and blowing, the waterdrop can be made to move down the tube.

AIR

EXPANSION BY HEAT

1.30. THE PAPER MERRY-GO-ROUND

- Materials:**
1. Two (5" x 8") paper cards.
 2. A needle or pin, masking tape, scissors.
 3. A pencil or straw, a lamp or candle and matches.

**Procedure:**

1. Draw a spiral on the paper card of about 1 cm width and cut out the spiral with scissors following the line (Sketch A).
2. Tape the needle or pin to the pencil or straw.
3. Balance the paper spiral on the needle point and hold it about 10 cm above a lit candle or lamp: the spiral turns!
4. Other types of merry-go-rounds can be made from paper cards or light paper (construction paper) (see Sketch B & C).

Questions:

1. What does the burning candle do to the air?
2. What will heated air do?
3. What does a windmill need to turn?
4. Why did the spiral turn?
5. Can we make other paper cut-outs that will spin?

Explanation:

The lamp or burning candle was the source of heat which heated the air. Hot air takes up a larger volume than cold air and is therefore lighter in weight. Thus hot air rises and by holding the paper spiral in this stream of air, it flows along the spiral and makes it turn.

Examples that are based on this same principle are the windmills, which only turn when there is a wind blowing. The air stream here, however, is flowing in a horizontal direction. The air stream which was moving the paper spiral moved in a vertical direction. Other paper cut-outs are drawn in figure B and C, which will also spin in a stream of air.

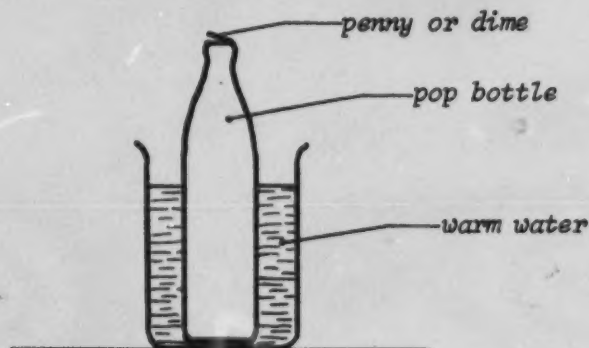
The needle point is the center point of rotation and it serves as a near frictionless set up for the rotation of the object. A very slow moving airflow would therefore be detectable.

AIR

EXPANSION BY HEAT

1.31. THE DANCING PENNY

- Materials:
1. One empty bottle with a narrow neck.
 2. One large beaker or container for warm water.
 3. A penny or dime, or other small coin.

Procedure:

1. Moisten the opening of the bottle and place the penny or dime flat on the bottle mouth.
2. Fill the large beaker with hot water (not steaming, so that it would look like cold water; if possible fill this container before doing the demonstration).
3. Immerse the bottle, which is covered with the penny, in the water and observe the dancing coin.

Questions:

1. What was in the bottle before covering it with the coin?
2. What kind of water was in the beaker?
3. What was the moisture on the bottle opening necessary for?
4. Why did the penny or dime go up and down (vibrate)?
5. Would it also vibrate without moisture on the opening of the bottle?

Explanation:

The bottle was filled with air before covering it with the coin. The moisture on the opening of the bottle functions as a seal between the inside and outside of the bottle. When the bottle is placed in the hot water, the air inside the bottle is heated and this causes the air inside the bottle to expand. The only way it can escape from the bottle is through the opening, and thus it has to lift the coin. The coin falls back, more air expands and lifts up the coin again. When this sequence of events happens quickly, a vibration of the dime is caused.

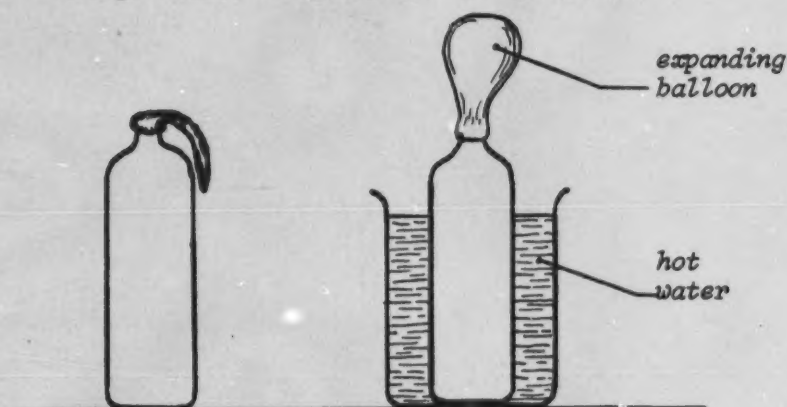
Without the moisture on the opening of the bottle, the coin does not seal off the air, so that the escaping air from inside the bottle could just seep under the coin out into the open without lifting the coin. The coin would thus not vibrate.

AIR

EXPANSION BY HEAT

1.32. THE LIVE BALLOON

- Materials:**
1. A small balloon (one that has been inflated before).
 2. A large bottle with a narrow neck.
 3. A large beaker or container for hot water.

**Procedure:**

1. If another identical bottle is available, put a few small things in this bottle; show the bottles to the students and ask them what is in the bottles (anticipated answer: 'nothing' in one of the bottles).
2. Place the small balloon over the mouth of the 'empty' bottle and let it hang limp against the side of the bottle (see Sketch A).
3. Fill the container with hot water (not steaming hot, if possible do not show students that it is hot water).
4. Immerse the bottle with the balloon on it in the hot water (the balloon will slowly fill with the expanding air) (see Sketch B).

Questions:

1. Before demonstration: What is in the bottle?
2. Why did the balloon inflate itself?
3. What kind of water do you think was in the large container?
4. How can we deflate the balloon without taking it off the bottle?
5. What does air do when it is heated?
6. Is there more or less air in the warm bottle compared to the cold one?

Explanation:

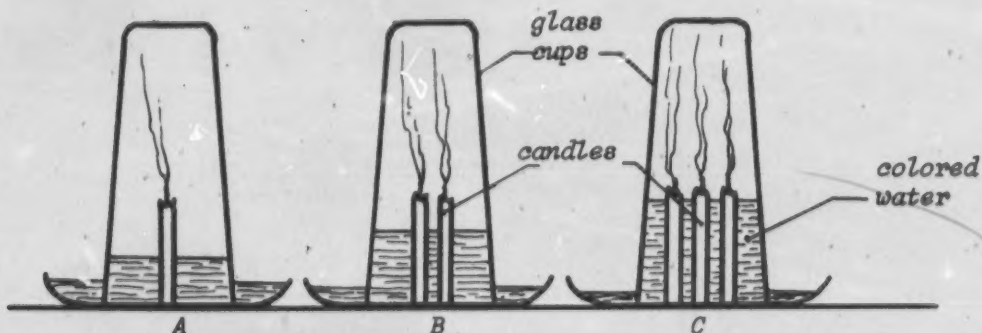
The bottle was filled with air at the moment that the balloon was put over it. The immersion of the bottle in the hot water heated the air inside the bottle, which made it expand and fill the balloon. The larger the bottle, the more air will expand, and the quicker the balloon will inflate. Taking the bottle out of the warm water and leaving it to stand on the table will cool it off and contract the air. This will deflate the balloon again. The amount of air is not changing, whether it is hot or cool, as no outside air was allowed in or out of the bottle. It is just the volume of air that is changing.

AIR

EXPANSION BY HEAT

1.33. WHAT CAUSES THE WATER TO RISE? (I)

- Materials:**
1. Three identical saucers or one large flat tray.
 2. Three identical glass cups.
 3. Six small birthday candles and matches.

**Procedure:**

1. Attach one, two, and three candles to the center of each saucer or at different spots of the tray (in case of using a flat tray).
2. Fill each saucer with at least $\frac{3}{4}$ cup of water.
3. Light all six candles and wait till they all burn evenly.
4. Place the three cups at the same time over the candles on the saucer like illustrated (let a student help you).

Questions:

1. Under which cup does the water level rise highest?
2. Why did we take identical saucers, cups and candles?
3. Do we need to pour the same amount of water in the saucers?
4. Which variable is manipulated or changed in comparing A, B, and C?
5. Above which saucer did heat develop most?
6. Was the amount of air trapped under the cups the same for all three?
7. Why did the water level rise highest in case C?

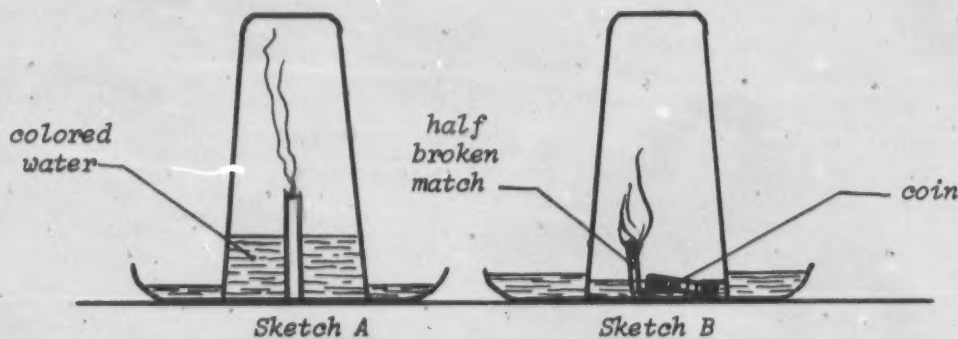
Explanation:

In all three cases the saucers, cups, and candles were identical. This meant that these variables did not influence the rising of the water level. The only variable that was changed or manipulated was the number of candles, and thus the amount of heat. This was the main factor causing the air under the cup to expand just before it hit the water, thus under cup C the trapped air was the least and thus exerting the lowest pressure. This is the reason why the water is pushed up the highest in cup C. Most students will think that the three candles will burn more oxygen, which is not the case. The use of oxygen for the burning process also helped in decreasing the pressure under the cups, but the amount of oxygen was the same for all three cases.

AIR

CONTAINING OXYGEN
EXPANSION BY HEAT1.34. WHAT CAUSES THE WATER TO RISE? (II)

- Materials:
1. A small saucer and a glass cup.
 2. A birthday candle or wooden matches and a coin.

Procedure:

1. Attach the candle in the center of the saucer with a drop of melted wax (see Sketch A), or if no candle is available: break a short end of a couple of matches halfway and place them vertically on the saucer (using a coin as a weight to support them: see Sketch B).
2. Fill the saucer with about half a cup of water.
3. Light the candle or the two matches and cover it immediately with the inverted cup. Observe the water level!

Questions:

1. Why did the water level under the cup rise?
2. What does the candle need in order for it to burn?
3. Did the water level under the cup rise immediately after covering?
4. What did the heat of the flame do to the air under the cup?
5. Would the burning of two or three candles bring up the water level under the cup to the same height?
6. How would the size of the cup influence the rising of the water level?
How can we set up experiments to test this?

Explanation:

The burning of the candle needs oxygen and is therefore taking away all the oxygen under the cup. The flame is extinguished as soon as all the oxygen is used up. As the space under the cup does not contain any oxygen any more, it is exerting less pressure compared to the atmospheric air. The water is therefore pushed into the space under the cup.

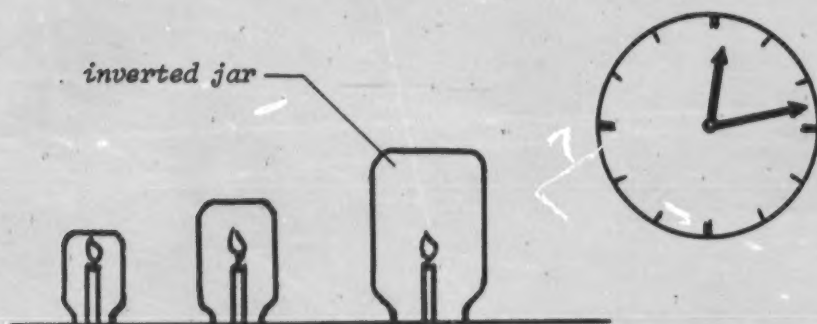
Another major factor contributing to the decrease of pressure inside the cup, is the fact that the heat of the flame expanded the air under the cup, just before it hit the water. At that moment air escaped from under the cup. After the flame extinguished, the remaining air cooled off and contracted and in so doing it sucked up the water.

AIR

CONTAINING OXYGEN

1.35. THE CANDLE UNDER THE JAR

- Materials:
1. Three or more jars of different sizes.
 2. Three or more birthday candles (depending on number of jars).
 3. A large clock or watches for timing the burning candles.

Procedure:

1. Divide the class in small groups of three to six students.
2. Give each group one jar, one candle and matches.
3. Make sure that the students can see the large clock or that each group of students have a watch for timing.
4. Ask the groups to measure the burning time of the candle under the jar: Start timing as soon as the jar is put over the candle and stop timing when smoke evolves from the wick (repeat several times, make sure to replenish the air in the jar).
5. Compare size (volume) of jar with the burning times (plot on graph).

Questions:

1. Why do we measure the burning time more than once?
2. What should we do to the gas in the jar before repeating the measuring of the burning time of the candle?
3. What do you think the burning time of the candle would be, if we did not replenish the air in the jar after the first reading?
4. Why did the candle stop burning under the jar?
5. How can we measure the volume of the jar?
6. What is the relationship between size or volume of the jar and the burning time of the candle?

Explanation:

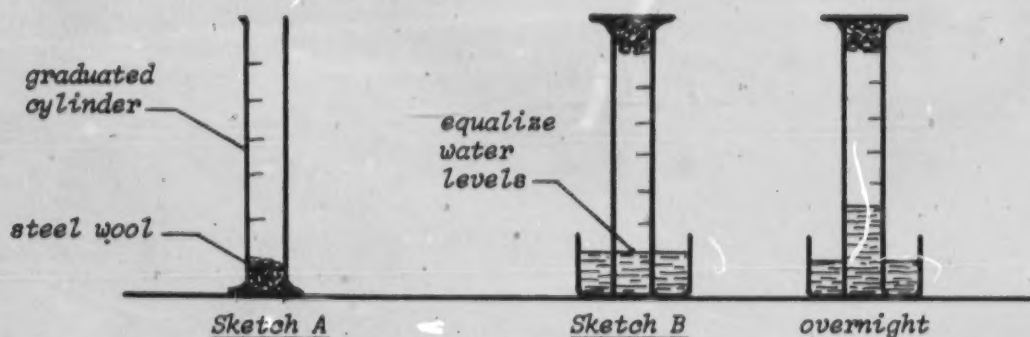
Air or actually oxygen in the air (about 20%) is needed to sustain the burning of the candle. After the first burning, the jar has no more oxygen. All the oxygen is replaced by carbon dioxide and water vapor, which can be seen condensing on the cold inside surface of the jar. Before doing a next timing of the burning candle, the air or oxygen in the jar has to be replenished. This can be done by pushing crumpled paper in and out of the jar several times. A straight line relationship exists between the volume of the jar and the burning time of the candle when the data are graphed.

AIR

CONTAINING OXYGEN

1.36. THE WATER-ATTRACTING STEEL WOOL

- Materials:**
1. Two graduated cylinders or two tall glasses.
 2. Two shallow dishes or trays.
 3. A small batton of steel wool.

**Procedure:**

1. Fill both shallow dishes with water.
2. Place the steel wool batton close to the bottom of one of the cylinders or tall glasses. (see Sketch A)
3. Wet this steel wool thoroughly by pouring some water in the cylinder.
4. Fill the cylinder one quarter full with water, cover it with a small paper card, place it upside down on the dish, and take the card out from under the inverted cylinder.
5. Adjust the water level in the cylinder evenly with the water level in the dish by letting an air bubble in the cylinder (holding it somewhat slanted) if the water level inside is too high (see Sketch B).
6. Repeat steps 4 and 5 with the other cylinder without the steel wool.
7. Place them side by side and leave them overnight. Observe water level!

Questions:

1. Why did the water level under the cylinder with the steel wool rise?
2. Did the steel wool change color? What happened to it?
3. What part of the volume in the cylinder did the water level rise?
4. What other chemical can we use in place of the steel wool?

Explanation:

The steel wool in the cylinder reacted with the oxygen in the air forming iron rust (Fe_2O_3). When all the oxygen under the cylinder has reacted with the iron, the water level should have risen about one fifth of the volume, since 20% of the air consists of oxygen. Having taken away the oxygen under the cylinder, the pressure of the remaining air is decreased, forming a partial vacuum and thus sucking the water level higher up.

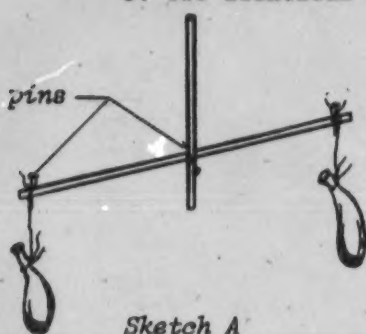
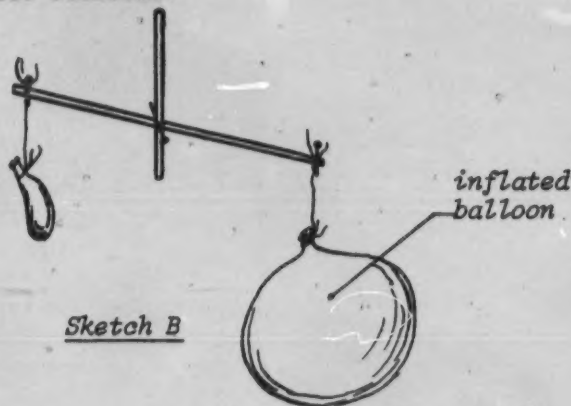
Magnesium ribbon or a chunk of white phosphorus may be used in place of the steel wool to bind the oxygen out of the air.

AIR

HAS WEIGHT

1.37. THE BALANCING BALLOONS

- Materials:
1. Two drinking straws.
 2. Three pins or needles & two pieces of thread.
 3. Two identical uninflated balloons.

Sketch ASketch BProcedure:

1. Tie a piece of thread to each of the two balloons and tie the threads to the two ends of one of the straws.
2. Balance this straw on your finger, push a pin through the straw where it is balancing and attach it to the other straw (see Sketch A).
3. Make sure that the straws are moving freely around the needle; balance the horizontal straw, then push a pin through at the spot where the threads are attached (to prevent them from sliding).
4. Make sure that the two uninflated balloons are in perfect balance; then blow air in one of them and tie a knot in the mouth. The balance will tip down at the end of the inflated balloon!

Questions:

1. What is inside the uninflated balloons?
2. What kind of air was blown in one of the balloons?
3. What could happen if no pins were placed on the ends of the horizontal straw where the threads were attached?
4. What does the balance indicate after inflating one balloon?
5. What would you expect the balance would do if the other balloon was also inflated?
6. How else could we show that air has weight?

Explanation:

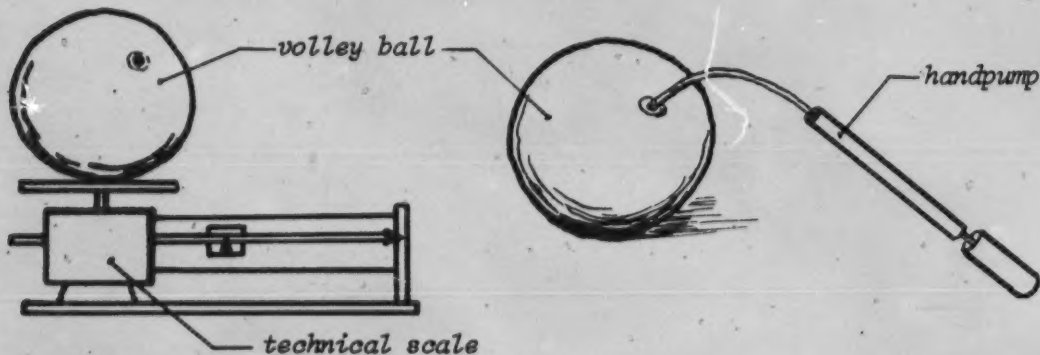
The straw balance may be adjusted by moving the threads further or closer to the end of the straw. In order to keep these attached threads from sliding, we need the pins. The air that was blown in the balloon was exhaled air, which is containing some water vapor but, for our purposes, may be neglected. By inflating the other balloon, the balance should be in equilibrium again.

AIR

HAS WEIGHT

1.38. THE BALL THAT GAINS WEIGHT

- Materials:**
1. A basketball or volleyball (with a valve).
 2. A handpump (to pump up the ball).
 3. A technical scale or balance (to weigh the ball).

**Procedure:**

1. Place a rather soft basketball or volleyball on the pan of the technical scale and determine the weight.
2. Connect the handpump to the ball and pump ten strokes or air into the ball.
3. Disconnect the pump and read off the weight of the ball. How much did the ball gain in weight?
4. Repeat steps 2 and 3, and have students predict what the gain in weight would be after 5, 10, 15, 20, 25 strokes of the pump.

Questions:

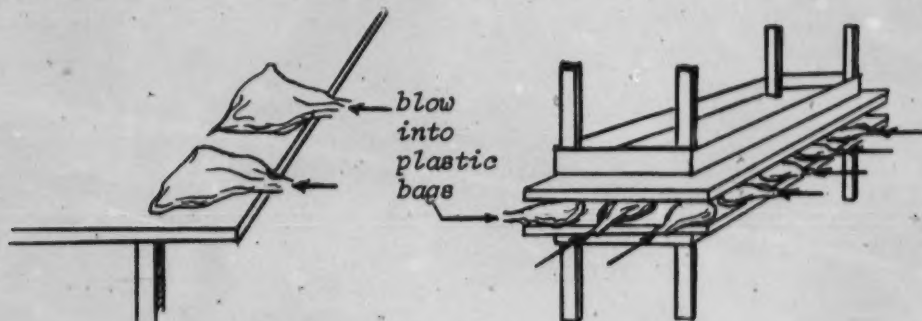
1. What made the ball gain in weight?
2. What can we say about the relationship between the number of pump strokes and the gain in weight of the ball?
3. How can we make the ball lose weight?
4. How much would a beachball gain in weight when pumped with 5, 10, or 15 strokes of the same handpump?
5. Would an airtight bottle gain weight if air were pumped into it?

Explanation:

This demonstration shows that *air has weight*. By adding air to the ball, it increases in weight. The same number of pump strokes should result in the same gain in weight. Half the number of pump strokes gives half the gain in weight. The number of pump strokes is therefore directly proportional to the increase in weight. If the data were plotted on a graph, a straight line relationship would be obtained between the number of pump strokes and the weight of the ball. Whether a ball or an air mattress or an airtight bottle is pumped, the increase in weight should be the same, provided that the same pump is being used and the same number of strokes is applied.

1.39. THE PLASTIC BAG AIR LIFT

- Materials:
1. Twelve to twenty medium size garbage bags (plastic).
 2. Two identical flat top tables.

Procedure:

1. Ask as many students as can possibly stand around one of the tables to stand around the table and give them each a plastic bag.
2. Let them spread the bags out on the table and hold the bag's mouth in their hands to get set to blow air in them (let the students stay in a squatting position around the table).
3. Make sure that all students are ready to blow air into the bags with their hands and fingers away from the table top!
4. Ask two or four other students to lift the other identical table, turn it upside down and put it slowly on the first table (this has to be done carefully as it has to move over the heads of the students!).
5. Ask one or two students to climb up and sit on top of the set of tables.
6. Let the squatting students now blow air in the plastic bags all together on the count of three.

Questions:

1. Did you expect a heavy weight like that to be lifted by air?
2. What made the top table rise?
3. How did the pressure of the air inside the plastic bags compare to the outside atmospheric air pressure?
4. Where do we find applications of this principle?

Explanation:

By blowing in the plastic bags, air is being compressed. This compressed air is exerting pressure underneath the inverted table causing the table to rise. This principle is being applied when pumping tires of a bicycle or automobile, or compressing air in air lifts (at gas stations or garages). Tire pressures are twice or four times as high as the atmospheric pressure, and in air lifts these pressures go as high as 20 to 50 atmospheres.

AIR

COMPRESSIBILITY
DENSITY OF MATERIAL1.40. THE OBEDIENT DIVER

- Materials:
1. A milk bottle or other jar, and a large beaker.
 2. A medium size test tube.
 3. A medicine dropper, wooden match, a large balloon.

Sketch ASketch BProcedure:

1. Fill the beaker with water; fill the dropper half way with water and test it in the beaker: it should just float (more or less water in the dropper will make it sink or float).
2. Fill the bottle brimfull with water and tie an uninflated balloon flat on the bottle opening (do this after you transferred the dropper from the beaker into the bottle).
3. Put your finger on the stretched balloon and control the sinking or floating of the dropper by putting pressure on it.
4. Ask the students to say "up" or "down" or "stop" and the dropper will respond to their command!
5. A broken off wooden match head in a water-filled test tube can be similarly controlled by pressure of the thumb (see Sketch B).

Questions:

1. What made the dropper or the match head sink? Or float?
2. What did the water level inside the dropper do when it dove down?
3. Did the air inside the dropper increase or decrease in volume during the diving? During the floating?
4. Is water or air more compressible?

Explanation:

By putting pressure on the stretched balloon with the finger, or with the thumb on the test tube, the air inside the dropper (or inside the wood fibers of the wood match) gets compressed, the water level rises and thus the whole dropper gets heavier and sinks. By releasing the pressure, the water is pushed out again, the dropper gets lighter and floats. This principle is applied in submarines, where water is pumped in to submerge or pumped out to surface. This demonstration is also suitable to initiate inquiry on *sinking & floating* or on *density*.

CHAPTER 2

WHAT CAN FLOWING AIR DO ?

OBJECTIVES

After dealing with and studying the concepts in this chapter, the students should be able to:

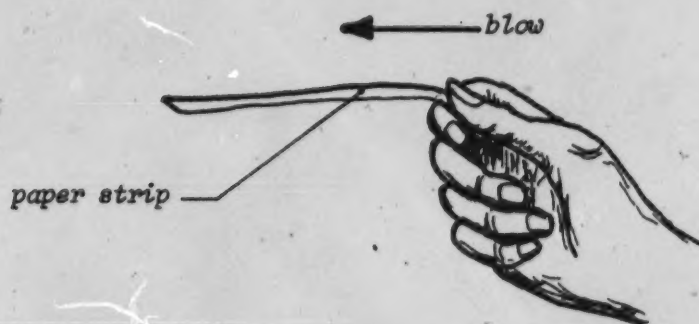
- a. recognize the correct explanation of an observed event based on the Principle of Bernoulli;
- b. distinguish true from false statements concerning events applying the Principle of Bernoulli;
- c. distinguish between air flow along a surface and air flow against a surface (wind energy);
- d. identify the correct explanation of an event in daily life applying the Principle of Bernoulli.

FLOWING AIR

BERNOULLI'S PRINCIPLE

2.1. THE LIFTING PAPER

Materials: 1. Strips of paper of about 15 x 3 cm (for each of the students).

Procedure:

1. Hand out a strip of paper to each of the students.
2. Have them make a fold at one end of the paper strip.
3. Holding the paper strip by the folded end, let them blow against the underside of the paper: what do you observe?
4. Now hold the strip near the chin and blow over it (let the students try and predict what will happen to the strip).

Questions:

1. What did you observe in the first instance? (blowing under it).
2. What did you observe in the second case? (blowing over it).
3. What do you know about the properties of stationary air?
4. What is different about the air on top of the paper compared to that underneath the paper, when we blow over it?
5. What effect does the moving air have on the gravity that is working on the strip of paper?

Explanation:

Stationary air exerts pressure in all directions. When we blow over the top of the paper strip, we are creating a faster moving flow of air above the strip. The faster the flow of a fluid (in this case the air), the lower the pressure it exerts (Bernoulli's Principle):

$$P + \frac{K.E.}{V} = \text{Constant, where } P = \text{Pressure, K.E.} = \text{Kinetic Energy and } V =$$

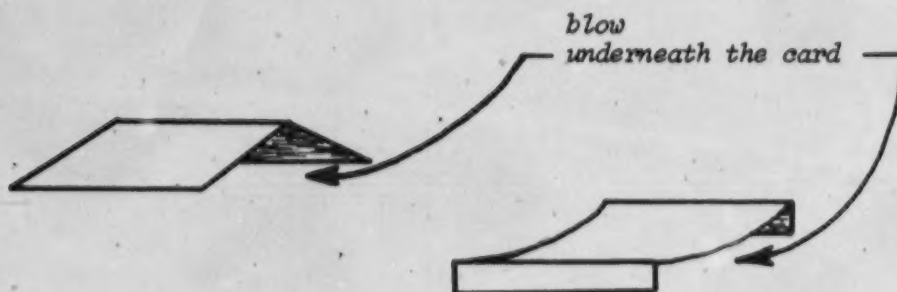
Volume. This last ratio can be equated with the velocity of the moving fluid. The effect of the moving air above the strip of paper is, that it reduces the pressure above the strip. Thus the higher pressure under the strip pushes the paper up into the lower pressure region.

FLOWING AIR

BERNOULLI'S PRINCIPLE

2.2. THE STUBBORN PAPER CARD

Materials: 1. Paper cards (3" x 5") for each of the students.

Procedure:

1. Distribute the 3 x 5 cards to each of the students.
2. Fold the cards either in the center (Sketch A) or fold them at each end about 1 cm from the edge (see Sketch B).
3. Place the folded card on the table or desk and try to blow the card off the table by blowing underneath it. What do you observe?

Questions:

1. What did you observe when blowing underneath the paper?
2. What properties does stationary air have?
3. What is different about the air underneath the paper compared to that above the paper, when blowing underneath it?
4. Why do you think the paper did not fly off the table?
5. What is different about flowing air compared to stationary air?

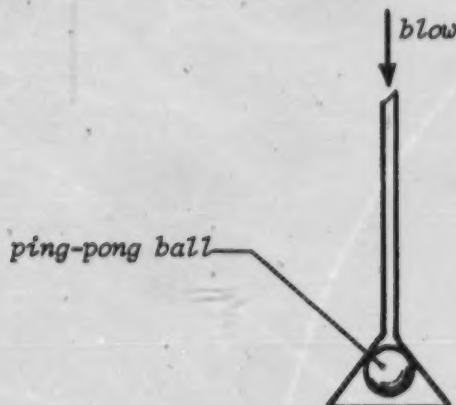
Explanation:

This activity can be a follow-up to 'The Lifting Paper' in dealing with Bernoulli's Principle. Among other properties, stationary air exerts pressure. Flowing air exerts less pressure as compared to stationary air. The faster the flow, the lower the pressure it exerts. By blowing underneath the card, we actually created less pressure underneath the paper, so that the pressure above the paper became larger than below the paper, and this is why the card got pressed down against the table.

In terms of moving molecules, we can see that by blowing underneath the card, the air molecules are pushed away from under the card. It is as if a partial vacuum is created at the spot where one is blowing. The air molecules that surround the card, those on the side as well as those above the air stream, are sucked towards this spot. In rushing to replace the molecules that were blown away, these air molecules push on the upper side of the card, thus bending it down towards the table.

2.3. THE FUNNEL AND THE BALL

Materials: 1. One long-stem funnel (glass or plastic).
2. One ping-pong ball.

Procedure:

1. Place the funnel and the ball next to each other on the table.
2. Ask: "How can I pick up the ball with the funnel without sucking through it? I may not touch the ball."
3. Pick up the funnel by the stem, place it over the ball and blow through the stem, lift the funnel while blowing.
4. Hold one hand under the funnel and stop blowing (ball drops).
5. Place the ball in the funnel and have a student try to blow it out of the funnel (he/she will not succeed).

Questions:

1. How did we pick up the ball with the funnel without sucking through it?
2. What happened when we stopped blowing?
3. Is it possible to blow the ball out of the funnel?
4. Where is the air moving fastest when we blow through the funnel?
5. What is flowing air creating that stationary air doesn't?
6. What is the difference about the inside compared to the outside of the funnel when blowing through it?

Explanation:

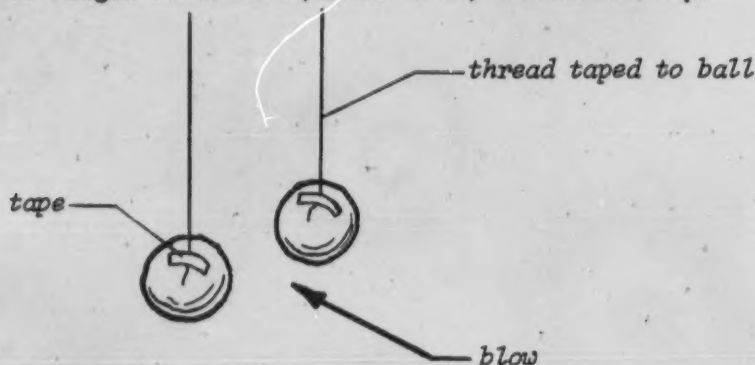
The ball can be picked up from the table with the funnel by blowing through it. By blowing through the funnel, we create a lower pressure inside the funnel, especially at the spot where the stem is attached to the conical shape of the funnel. Here the fastest flow of air occurs, because the air molecules have suddenly more space to move about. *The faster the flow of air, the lower the pressure.* This is why the ball is sucked into the funnel by blowing, and for the same reason it is not possible to blow the ball out of the funnel. The harder we blow through the funnel, the lower the pressure gets in the mouth of the funnel.

FLOWING AIR

BERNOULLI'S PRINCIPLE

2.4. THE ATTRACTING SPHERES

- Materials:
1. Two plastic spheres (tennis balls or apples will work).
 2. Two length of thread (about 40 cm) & adhesive tape.

Procedure:

1. Tape the two pieces of thread to the two spheres.
2. Hang the two spheres about 3 cm apart from a horizontal support, or let someone hold them.
3. Ask: "What would you expect the balls to do when I blow in between them?" (anticipated answer: fly apart).
4. Blow in between the two hanging spheres and observe the movement of the two spheres (hard plastic spheres will click together).

Questions:

1. What do you observe when blowing straight against one ball?
2. What did you expect the two spheres would do when blowing between them?
3. What did you observe the two spheres were doing when blowing in between?
4. What did we create between the balls by making the air flow?
5. What is different about the air between the two spheres as compared to the surrounding air?

Explanation:

When blowing head on against one sphere, we observe that the sphere moves away from the source of the air flow. This is because the air molecules bump directly against the surface of the sphere, the kinetic energy is transferred to the sphere and it is thus pushed away. When blowing in between the two spheres, we are actually pushing away the air molecules and thus creating a lower pressure. The stationary air surrounding the two spheres on the outside exerts a higher pressure and pushes them against each other.

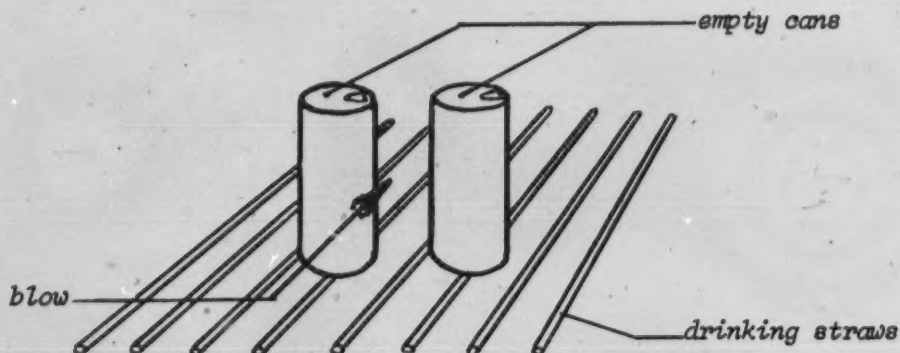
Applications of Bernoulli's Principle with spheres are encountered in playing tennis or baseball. A top spin in tennis creates a stronger and faster air flow under the ball and curves the path down (in court). A spin throw of a baseball curves the ball path in the direction of the spin.

FLOWING AIR

BERNOULLI'S PRINCIPLE

2.5. THE CLANGING SODA-POP CANS

- Materials:
1. Two empty soda-pop cans.
 2. About two dozen straight drinking straws.

Procedure:

1. Spread the straws parallel to each other on the table and leave about $\frac{1}{2}$ to 1 cm gap in between them.
2. Place the two cans upright about 2 cm from each other on the straws and show the students that they can easily move closer or further apart.
3. Ask: "What will happen to the cans if I blow in between them?" Blow in between the two cans with a short hard puff (Cans clang!).
4. Now spread the two cans about 5 cm apart. Ask: "Do I have to blow softer or harder to get the two cans clanging?" Blow harder!
5. Now place the cans about 20 cm apart. Ask: "Can I still get the two cans clanging against each other?" Take a deep breath and blow a constant stream of air on the right side of the left can and move your head towards the right, while constantly blowing (Cans will clang!).

Questions:

1. What made the cans move towards each other?
2. How far apart could the cans be placed and still be drawn together?
3. What does the flowing air create in between the cans?
4. Was a stronger flow of air necessary to bring the cans that were 20 cm apart together?

Explanation:

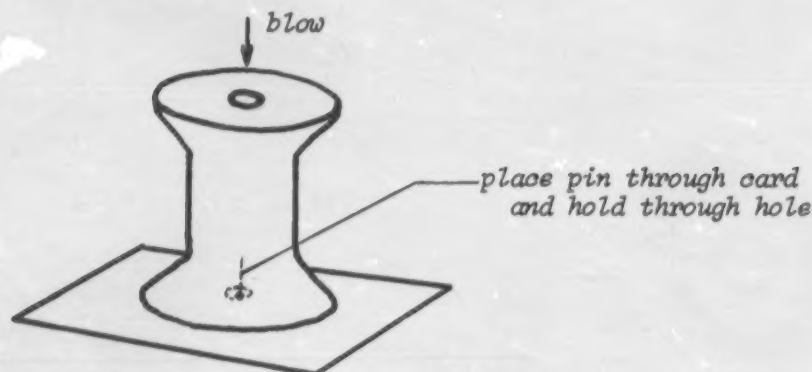
Blowing in between the cans created a flow of air and thus a lower pressure compared to the stationary air on the other side of the cans. It is this lower pressure that drew them together. Theoretically, the cans could be placed an infinite distance away from each other and still be drawn together, as long as a constant flow of air on one side of one can moves along with it, to move it to the other can. Indeed, the faster the flow of air, the lower the pressure it exerts. But for the cans that were placed 20 cm apart, only a constant flow that could move with the can, was necessary.

FLOWING AIR

BERNOULLI'S PRINCIPLE

2.6. THE FLOATING CARD

- Materials:
1. A paper card (3 x 5").
 2. A thread spool and a pin.

Procedure:

1. Hold the card up close to the mouth and blow against it. What do you observe? What did the card do?
2. Now push the pin through the center of the card.
3. Hold the card against the spool with the pin sticking in the hole of the spool. Ask: "What would you expect the card to do when I blow through the hole of the spool?" (Anticipated answer: 'blow away').
4. Now blow through the hole of the spool and let go of the card (card should stick against the spool).

Questions:

1. What did you observe when blowing against the card without the spool?
2. What did you observe when blowing through the hole of the spool against the card?
3. Where was the faster flow of air created?
4. What is different about the air above the card as compared to the air under the card (while blowing through the spool hole)?
5. What is keeping the card against the spool?

Explanation:

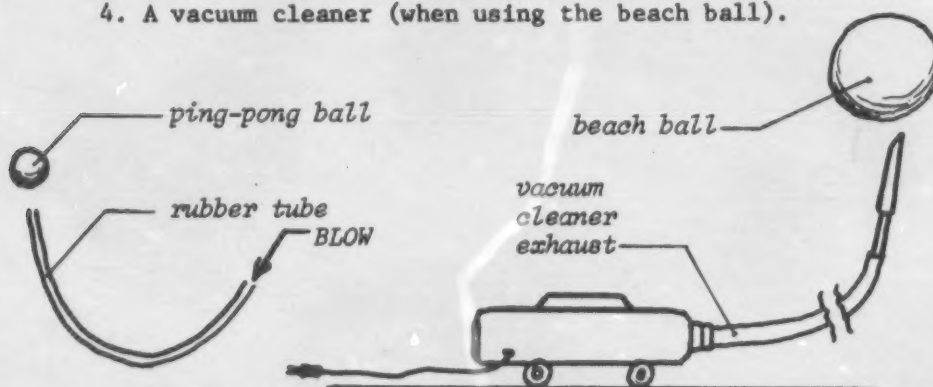
By blowing in the hole of the spool, we are creating a faster flow of air above the card, thus creating a partial vacuum at this spot: between the card and the spool. The relatively slower moving air, which is surrounding the card, exerts a higher pressure compared to the air between the card and the spool. This makes the card stay close to the spool. As soon as we stop blowing through the spool, the card drops, because the pressure above and below the card is equalized.

FLOWING AIR

BERNOULLI'S PRINCIPLE

2.7. THE FLOATING BALL

- Materials:
1. A ping-pong ball or a beach ball.
 2. A 25 cm length of rubber tubing.
 3. A small compressor to produce a constant air flow (optional).
 4. A vacuum cleaner (when using the beach ball).

Procedure:

1. Take the rubber tubing with each hand on one end of the tube.
2. Place the ping-pong ball on one end of the tubing and blow through the other end, and balance the ball in the air flow.
3. When using a beach ball, you will need a vacuum cleaner. Detach the vacuum cleaner hose and attach it to the exhaust end, so that it blows through it rather than producing a suction.
4. Blow air into the beach ball and let the ball hang in the air stream that the vacuum hose is producing.
5. When a small compressor is available, attach a small orifice to the exhaust tube and hang a ping-pong ball in the air stream.

Questions:

1. Will we be able to do the same thing with other round objects?
2. What property of the round object is critical for it to stay afloat?
3. What does the blowing do to the movement of the air molecules?
4. How does the pressure of flowing air compare to that of stationary air?
5. Why does the ball stay afloat in the air stream?

Explanation:

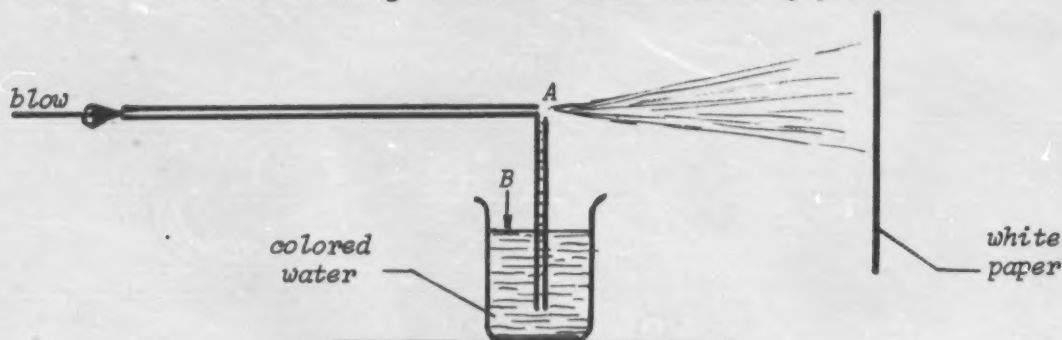
By blowing through the rubber tubing or by using the compressor or the exhaust of the vacuum cleaner, we are creating an air flow. This air flow causes the existence of a lower pressure area compared to the surrounding air, which is stationary or not moving as fast. *Bernoulli's Principle* states that: *the faster the flow of air, the lower the pressure*. This means that at the place of exhaust (end of the tube or hose), a cone of lower pressure is created. All the surrounding air is exerting a higher pressure and thus the ball is kept in the lower pressure area, which is the cone above the exhaust.

FLOWING AIR

TECHNOLOGICAL APPLICATION

2.8. LIFT WATER BY BLOWING

- Materials:
1. Two drinking straws (transparent ones).
 2. A glass or beaker.
 3. Food coloring or ink & a white sheet of paper.

Procedure:

1. Fill the beaker about 3/4 full with water and add a few drops of food coloring or ink to it, and stir.
2. Cut one of the straws in half and dip this short straw vertically in the colored water (hold this with the left hand).
3. Place the long straw with the right hand horizontally against the top opening of the vertical straw (see Sketch above).
4. Ask a student to hold a white sheet of paper on the other side of the equipment set-up.
5. Blow through the horizontal straw until the colored water is sprayed against the paper. (The horizontal straw might need some adjusting up or down against the vertical one before the water comes out).

Questions:

1. What do you create by blowing the air with the straw?
2. How does the pressure at the meeting place of the two straws compare with that on the water surface of the beaker?
3. What is it that lifts the water in the vertical straw?
4. Would this also work with a longer vertical straw?
5. Where do we find this principle applied?

Explanation:

By blowing through the horizontal straw, we are creating a flow of air and the faster the flow of air, the lower the pressure (Bernoulli's Principle: see Event 2.1.). Thus the pressure at A is smaller than at B (see Sketch), and this pressure difference makes the water move upwards in the vertical straw. The longer the vertical straw, the harder we have to blow to create a larger pressure difference.

Applications of this principle are found in spray guns for painting, in spray bottles, spray pressured cans, etc.

FLOWING AIR

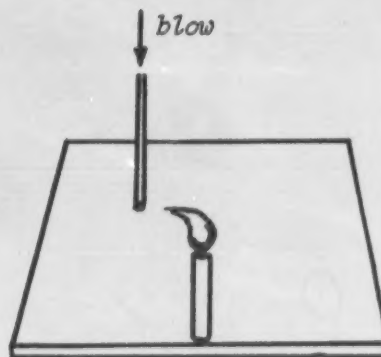
BERNOULLI'S PRINCIPLE

2.9. THE MYSTERIOUSLY MOVING FLAME

Materials: 1. A candle and matches & a drinking straw.



Sketch A



Sketch B

Procedure:

1. Light the candle and attach it to the table.
2. Blow through the straw directly against the flame, such that the students get the side view of it (Sketch A).
3. Now hold the straw to the side of the flame, blowing straight into the face of the observer, ask: "Where will the flame move to when I blow? Towards or away from the straw?" (Sketch B).
4. By moving the straw radially in a semi-circle and repeating point 3, make sure that every student has a good view of the moving flame.

Questions:

1. Why did the flame move away from the straw in set-up A?
2. Why did the flame move towards the straw in set-up B?
3. What variable is decreased by increasing the flow of air?
4. What principle is this phenomenon based on?
5. Where do we find this principle applied in daily life?

Explanation:

This event again is based on Bernoulli's Principle, which states that *the faster the fluid flows, the lower the pressure the fluid exerts*. In this case the fluid is air. The air on the straw side of the flame is flowing and thus compared to the air on the other side of the flame, which is stationary, it exerts a lower pressure. For this reason the flame bends toward the straw. When blowing straight against the flame, this latter gets immediately into the air stream and can be compared to a flag waving in the wind.

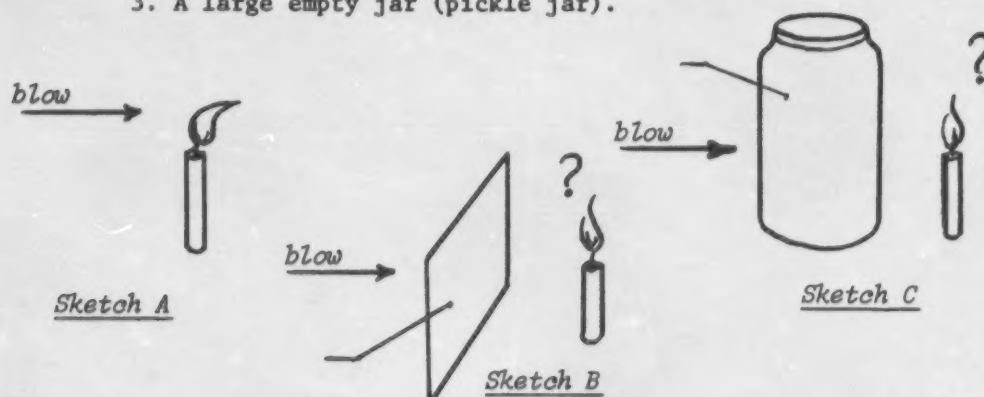
Applications of Bernoulli's Principle are encountered in our daily life in the lift that airplanes are getting when flying; the shape of the wings makes the air flow faster over the wing than under it (Event 2.11.). Other applications are found in throwing curved balls in baseball pitching and in using top spins in playing tennis.

FLOWING AIR

TURBULENCE

2.10. WHICH WAY WILL THE FLAME FLICKER?

- Materials:
1. A candle and matches.
 2. A paper card (3 x 5" or 10 x 15 cm).
 3. A large empty jar (pickle jar).

Procedure:

1. Light the candle and attach it to the table.
2. Stand to the side of the candle and ask: "Which way will the candle flame flicker when I blow from this side?"
3. Blow slowly against the flame: the flame moves away from you (Sketch A).
4. Place the card vertically between you and the candle, and ask again: "Which way will the candle flame flicker when I blow?"
5. Blow hard against the card and let students observe the flame. (B)
6. Place the empty jar between you and the burning candle. Repeat the question and blow hard against the jar (see Sketch C).

Questions:

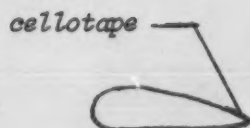
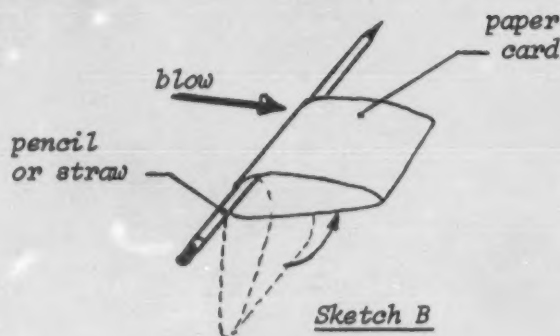
1. What does flowing air against the card create?
2. From your observation of the candle flame movement with the card, on which side of the candle was the air pressure lower?
3. Why did the candle flame not behave in the same way with the jar as with the card when blown against?
4. What would happen with the candle flame behind the jar, if we blew really hard against the jar?
5. Why are fast moving vehicles almost never squared off at the rear?

Explanation:

Blowing air against the card creates a turbulence of air behind the card and thus a lower pressure. The flame is drawn to the spot of lower air pressure and therefore is bent towards the card. When blowing against the jar, the air can smoothly flow around the jar and when the blowing occurs hard enough, the flame can easily be extinguished. This is an example of a streamlined fast moving object. Vehicles that are squared off at the rear have problems with turbulence, which is creating a pocket of low pressure in the rear of the vehicle, forming a drag.

2.11. THE PAPER WING

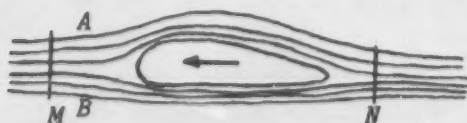
- Materials:
1. A piece of paper or paper card and cello tape.
 2. A round pencil or straw.

Sketch ASketch BProcedure:

1. Cut a piece of paper of about 5 x 15 cm and bend it in the shape of an airplane wing (Sketch A) and tape the ends together.
2. Put a pencil or straw through the wide end of the wing and let the paper wing hang vertically down (see Sketch B).
3. Blow over the paper wing (it should move up horizontally).

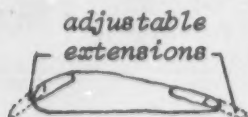
Questions:

1. Why does the paper wing move up when blown over it?
2. What would happen if you blew under the paper wing?
3. What happens if you blow over the wing, but invert it (with the curved side facing down)?
4. What gives airplanes the air lift?
5. What do airplanes do with their wings when they take off or land?

Explanation:

Bernoulli's Principle is underlying and causing the airlift that the airplane wing provides. The wing is built in such a way that the air over it flows faster than the air under it. It has a greater curvature on the top compared to the bottom side.

When we consider an air molecule A on the top side and molecule B below the wing, and they have to run from point M to N, it can be seen that A has to run faster than B, because of its longer path.



cross section of airplane wing

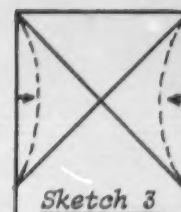
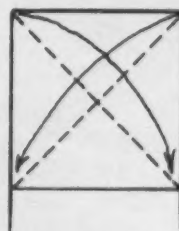
The wings of an airplane are provided with adjustable flaps that can be extended or retracted. When extended, it increases the curvature of the wing on the upper side and provides a greater lift for starting and landing.

FLOWING AIR

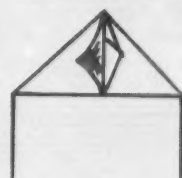
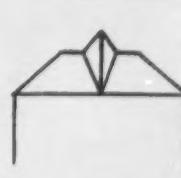
FLIGHT

2.12. THE PAPER AIRPLANE CONTEST

- Materials:
1. Onion skin or tracing paper.
 2. Small scissors (for each pair of students).

Sketch 1Sketch 2Sketch 3Procedure:

1. Take a rectangular shape of thin paper (10 x 20 cm) and make two creases AA' and BB' by bringing over B to B' and A to A' (Sketch 2).
2. Lift the middle of AB' = C and the middle of BA' = D up (Sketch 3) and push points A and B down over B' and A' (Sketch 4).
3. Now lift point B up and bring over to point M. Do the same with flap A, and crease the fold (Sketch 5).
4. Pinch flap F and fold over towards the front (point M), and do the same with flap E (Sketch 6).
5. Fold point M towards the back side of the paper (Sketch 7) and fold along the axis of symmetry to obtain Sketch 8.
6. Cut the plane in any shape you want (experiment with it) and bend wings up or down, and tail elevators up or down.
7. Fly the planes: the longest one to stay up wins (Sketch 1).

Sketch 4Sketch 5Sketch 6Sketch 7Sketch 8Questions:

1. What makes the paper plane fly farthest?
2. What makes the paper plane turn to the left or right?
3. Would thinner or thicker paper make the plane fly farther or longer?

Explanation:

When the elevators are angled up, the flowing air pushes it down and the plane climbs. The rudder works just like that of a boat. Turning it to the right moves the tail to the left and the whole plane turns to the right.

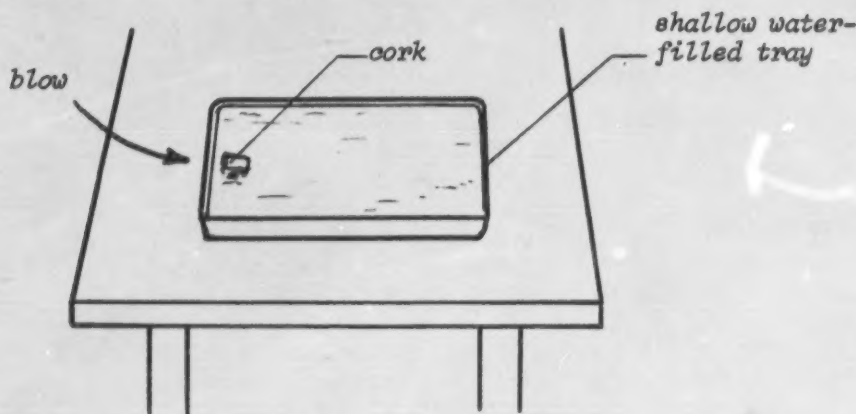
Ailerons are used to roll the plane and the flaps to increase the curvature of the wing and increase the lift.

FLOWING AIR

WIND ENERGY

2.13. THE CORK RACE

- Materials:
1. Different size corks (one per pair of students).
 2. A shallow tray (one per pair of students).

Procedure:

1. Distribute one cork and one tray to each pair of students.
2. Let the students fill the tray with water and float the cork on the water (making sure that the cork does not drag on the bottom of the tray; add more water if this is the case).
3. Position the students facing each other with the tray in between them (the cork may not be touched during the race).
4. On the count of three, one student blows the cork across the tray, and the other student indicates (raises hand) as soon as the cork has crossed over (reached the other side).

Questions:

1. What made the cork move over the water?
2. Which cork moved faster: the smaller or the larger one?
3. What are other factors that influence the speed of the moving cork?
4. What type of energy was used to move the cork?
5. Which side of the cork, when blown against, results in a faster speed?

Explanation:

The flowing air blowing against the cork consists of a stream of moving air molecules possessing kinetic energy. This energy is imparted upon the cork resulting in its movement. The speed of the cork depends on how hard one blows against the cork, whether the stream of air hits the upright ends or the round surface of the cork, and whether it is a larger or smaller cork. The larger cork has a larger surface to blow the air against and thus may move faster, even though it is slightly heavier than the smaller cork. Other variables influencing the speed might be investigated like: the type of liquid, the angle of air flow, etc.

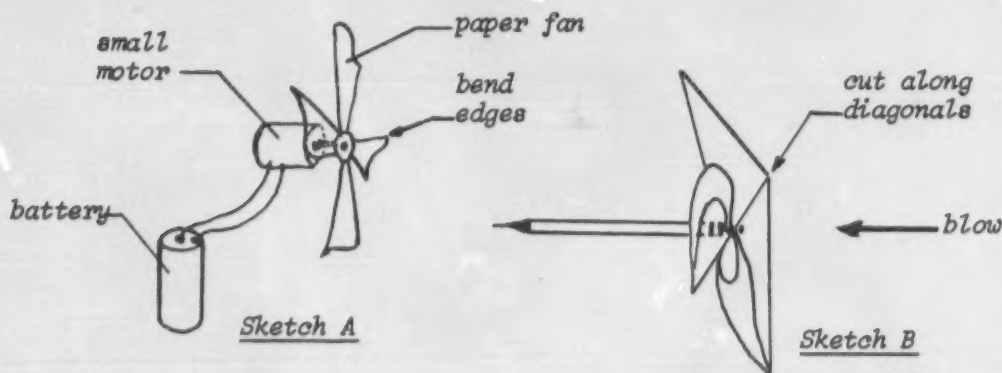
This demonstration shows that moving air is a form of energy: kinetic energy of moving air molecules.

FLOWING AIR

WIND ENERGY

2.14. THE PAPER FAN

- Materials:**
1. A paper card (5 x 8") or construction paper.
 2. A small DC motor & battery (for activity A).
 3. Straight pins & cello tape (for activity B).

**Procedure:**

1. Cut a circle (12 cm/5" diameter) out of the paper card.
2. Draw four diameters perpendicular to each other on the circle and cut in with scissors till about 1 cm from the center.
3. Cut four sections off and bend the edges of the remaining sections (see Sketch A), and attach this fan to the small motor. Switch the motor on (connect to battery): a flow of air is created.
4. For activity B no motor is needed.
Cut a square piece out of construction paper, draw the diagonals and cut along these lines till about 2 cm from the center.
5. Fold every other point back to the center and hold them in by pushing the straight pin through the points and the center of the paper.
6. Push the pin into the eraser part of a pencil and hold the paper mill in a stream of air, or move it back and forth in the air (Sketch B).

Questions:

1. What type of energy was transformed into the air flow in activity A?
2. Which way would the wind blow if the fan were turning in the opposite direction (in activity A)?
3. What type of energy did the air flow in activity B create?
4. What is needed to turn the paper mill in activity B?

Explanation:

In activity A electric energy was transformed into mechanical energy: the moving of the paper fan. This in turn made the air flow, which is kinetic energy of the air molecules. If the fan would turn in the opposite direction, the air flow would also be reversed.

With activity B, the kinetic energy of the air flow is transformed into mechanical energy: the turning of the paper mill. In order for this mill to turn, wind or a moving flow of air is needed.

CHAPTER 3

WHAT FACTORS ARE INFLUENCING THE WEATHER ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts of this chapter, the students should be able to:

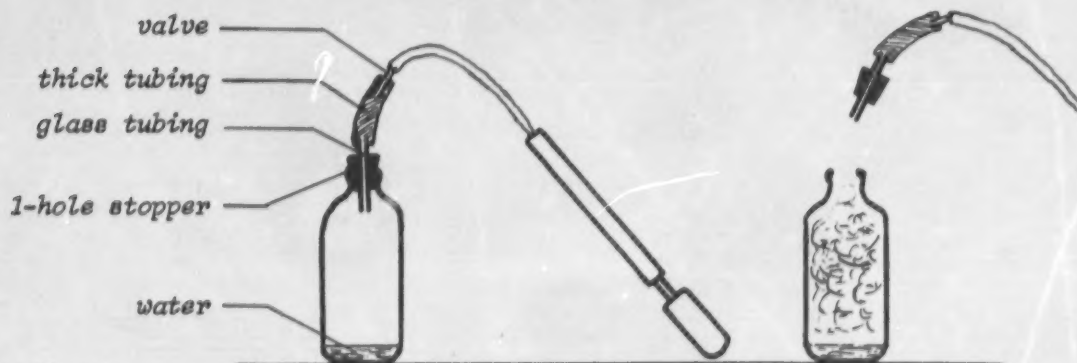
- a. recognize the correct explanation of the influence of atmospheric pressure, wind speed and direction, and humidity on the weather;
- b. explain correctly in their own words how atmospheric pressure, wind speed and direction, temperature and humidity are measured;
- c. distinguish true from false statements concerning each one of the variables influencing the weather;
- d. identify the correct explanation concerning variables that influence the climate, length of days, and the sun's heat.

WEATHER

PRESSURE

3.1. A CLOUD IN A BOTTLE (I)

- Materials:**
1. A colorless transparent soda-pop bottle.
 2. A bicycle hand pump & bicycle tire valve.
 3. A 1-hole stopper with short glass tube (fitting the bottle).
 4. A short piece of thick walled rubber tubing.

**Procedure:**

1. Place a few millilitres of water in the bottle.
2. Insert the 1-hole stopper tightly in the bottle opening and connect the bicycle pump as shown in the sketch.
3. Pump air into the bottle and let the students observe the bottle very carefully, especially the moment when the stopper pops out.
4. When the cloud is not too visible, drop a lit match in the bottle or blow a little smoke in the bottle, then repeat point 3.

Questions:

1. What do we need the water in the bottle for?
2. At the moment that the stopper pops out, what does the air inside the bottle do?
3. At the moment that the stopper pops out, what is the temperature of the air inside the bottle doing?
4. What will water vapor do when it is cooled?
5. Why do we get a better cloud with a little smoke in the bottle?
6. Where do we see applications of this principle (with the smoke) in our daily life?

Explanation:

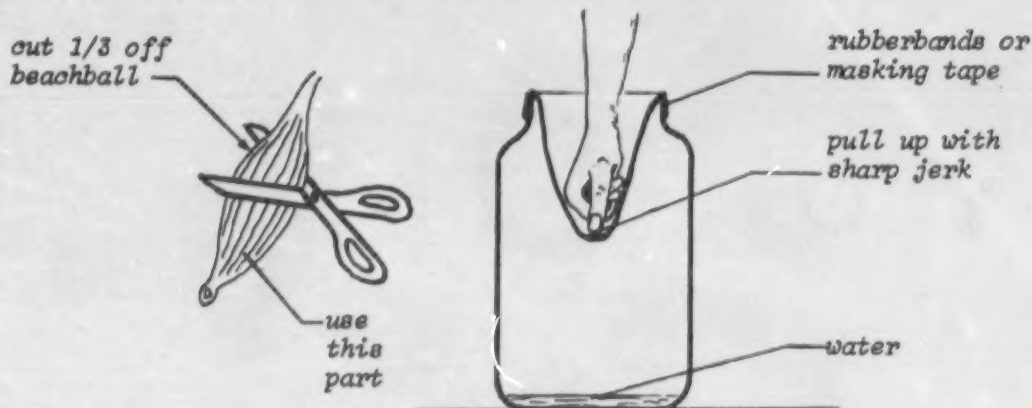
At the moment that the stopper pops out, we get a sudden low pressure in the bottle. The miniature atmosphere in the bottle had a high humidity because of the presence of the water. At the moment that the stopper pops, the air in the bottle rushes out, the temperature drops as air expands, and the water vapor condenses. This condensation process is enhanced by the presence of smoke, which is a suspension of solid particles in the air acting like nuclei for the water vapor to condense on. This is the reason why it is more likely that it will become foggy or rainy over polluted areas, such as larger cities with heavy industry, than over rural areas that have no industry.

WEATHER

PRESSURE

3.2. A CLOUD IN A BOTTLE (II)

- Materials:
1. A wide mouth gallon jar (pickle jar).
 2. An uninflated rubber beachball.
 3. Some heavy rubber bands or masking tape.

Procedure:

1. Place a few millilitres of water in the gallon jar.
2. Drop a lit match or blow some smoke in the jar.
3. Cut one third off of the beachball (Sketch A) and turn the larger part inside out. Place it over the jar, such that the cut edge slips over the rim of the jar, then fasten it with a few heavy rubberbands or masking tape around the jar mouth (make sure it is air tight).
4. Pull the rubber sheet up with a short sharp jerk and observe what is happening in the jar (see Sketch B).

Questions:

1. What function does the water in the jar have?
2. What do we need the smoke in the jar for?
3. What is suddenly increased by pulling the rubber sheet up?
4. How does the pulling of the rubber sheet affect the temperature?
5. Why is it usually more cloudy and foggy over industrial areas as compared to rural areas?
6. What would happen if the rubber sheet was not put on the jar airtight?
7. Would the cloud be more easily formed if the bottle were warm or cold?

Explanation:

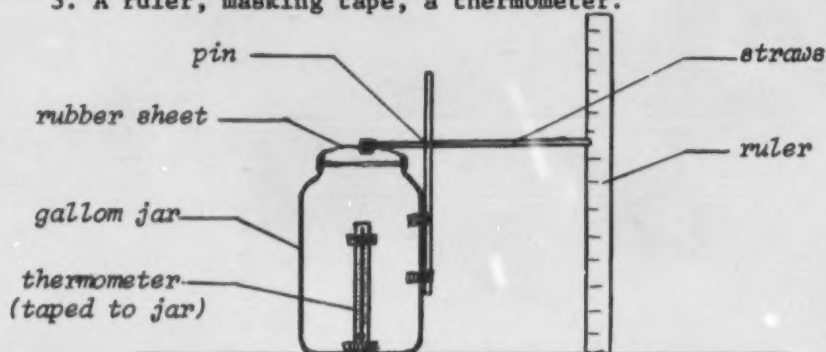
The water in the jar is necessary to create a miniature atmosphere with a high humidity. The smoke provides the nuclei on which the water vapor can condense when the rubber sheet is suddenly pulled up. This pulling up of the rubber sheet causes the volume of the air inside the jar to suddenly increase, and thus the temperature to decrease. As the humidity is very high, the air contains the maximum capacity of water vapor. The slightest drop in temperature, therefore, is enough to cause the water vapor to condense and produce a mist or fog.

WEATHER

PRESSURE

3.3. THE JAR BAROMETER

- Materials:
1. A wide-mouth gallon jar (pickle jar).
 2. A large balloon, 2 straws, a straight pin.
 3. A ruler, masking tape, a thermometer.

Procedure:

1. Blow the balloon up (preferably a day before use or a few hours before use) so that the rubber is stretched.
2. Cut a piece off the stretched balloon (large enough to cover the jar opening) and tape it airtight to the jar mouth.
3. Tape two straws pivoted with a pin to the center of the rubber sheet and to the side of the jar (see Sketch).
4. Place the jar such that the straw indicator points along a ruler.
5. Place a thermometer close to the jar or tape it to the jar, and read the pressure off the ruler at the same temperature, twice a day.

Questions:

1. When the atmospheric pressure gets higher, will the reading on the ruler be higher or lower?
2. Why is it necessary to stretch the rubber sheet beforehand?
3. Why does the reading of the pressure have to be done at the same temperature? What would a higher temperature do to the reading?
4. What does an increasing atmospheric pressure indicate for the weather forecasting?
5. What does a decreasing atmospheric pressure indicate?

Explanation:

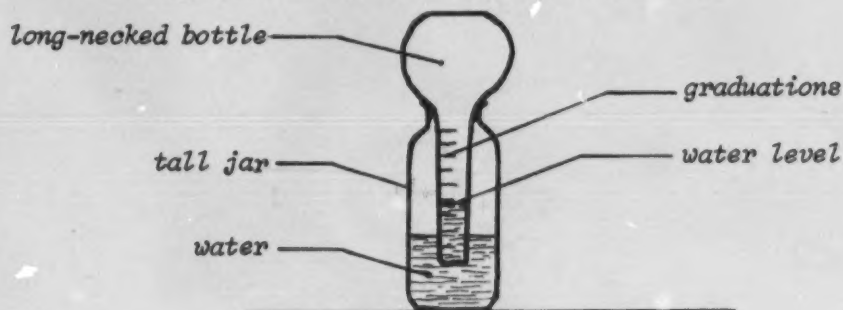
This simple barometer is only good for measuring relative atmospheric pressure changes. The ruler could be calibrated by listening to radio announcements of atmospheric/barometric pressures. The rubber diaphragm is more sensitive to pressure changes, when it is more flexible; that is why it needs prestretching. The reading of this simple instrument has to occur at the same temperature, as an increase in temperature will result in expansion of the air inside the jar, and thus a higher pressure in the jar and a lower reading. Cooling of the jar results in contraction of the air in the jar and thus a higher reading.

WEATHER

PRESSURE

3.4. THE BOTTLE BAROMETER

- Materials:
1. A bottle with a long narrow neck.
 2. A cylindrical tall jar & thermometer.
 3. A grease marker (a felt marker will do).

Procedure:

1. Find a bottle with a long narrow neck and a jar that can support the wider part of the bottle when inverted in the jar.
2. Draw horizontal even graduations on the bottle neck with a marker and assign numbers to the graduations (hold bottle upside down).
3. Fill the jar half full with water.
4. Pour some water in the bottle and invert it quickly into the slanted held jar, so that the water level in the bottle neck will be slightly higher than that in the jar.
5. Position the bottle barometer in a place where the temperature does not fluctuate, and read off the water level in the neck. Do this twice a day and compare readings.

Questions:

1. What should the water level in the bottle neck do if the atmospheric pressure increases? If it decreases?
2. Why does the barometer have to be put in a place where the temperature does not fluctuate?
3. At what point do these bottles function as a barometer?

Explanation:

When the atmospheric pressure increases, the water level in the jar is pushed down and thus pushed up in the bottle neck. When the pressure decreases, the water level in the jar goes up and thus the water level in the bottle neck goes down.

This simple barometer will only work when the surrounding temperature stays constant. When the surrounding temperature increases, the bottle and the air inside it warms up and expands, pushing and exerting pressure against the water resulting in a lower reading of the water level. A cooler surrounding temperature has the opposite reaction as a result.

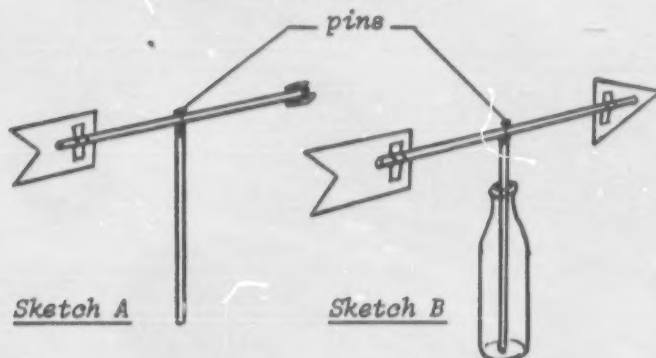
Over a longer period of time, the water of the jar will evaporate and water has to be added to bring the water level back up to its original level. Otherwise it ceases to function.

WEATHER

WIND

3.5. WHICH IS THE BEST WINDVANE ?

- Materials:
1. Drinking straws, straight pins, paperclips.
 2. Cellotape, paper cards, clay, scissors.
 3. An empty soda-pop bottle.
 4. A small electric fan.

Procedure:

1. Provide students with straws, paper cards, pins, scissors, cellotape, paperclips (pop bottles if available).
2. Ask students to construct a good working windvane (the best one will turn fastest into the wind direction).
3. Ask students what the conditions are for the windvane to work.
4. If students have trouble making one, give them clues by first constructing windvane A (see Sketch A):
Tape a piece of card to the end of a straw and insert some paperclips to the other end, find the balancing point (by letting it balance on your finger) and stick a pin through the straw at that point. Let this straw swivel in a vertically held straw.

Questions:

1. What is the difference between the front and the rear part of the windvane? Is there a difference in area?
2. What must the horizontal bar be able to do to turn in the direction of the wind?
3. Where must the pivot of the arrow (horizontal bar) be located?
4. What can be used as a base or stand for the windvane?
5. How would you construct a windvane that points where the wind is blowing to (opposite to where it comes from)?

Explanation:

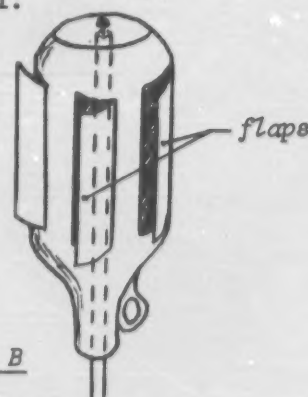
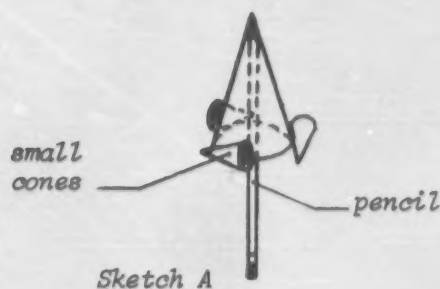
In order for a windvane to work, one end must be wider in surface area than the other end. By taping a cut-out card to one end of the straw, we increase the area at this end, but the weight at this end is thereby also increased. To counterbalance this, paperclips are inserted at the other end. This makes it possible to place the pivot in the center of the bar.

WEATHER

WIND

3.6. HOW FAST DOES THE WIND BLOW?

- Materials:
1. Paper cards (3 x 5"), cellotape, scissors.
 2. An empty plastic bottle with a narrow neck.
 3. A wooden stick (round), knife, nail.
 4. A small electric fan.

Procedure:

1. Fold four paper cards into cones and cut them into one large and three small cones. Tape the small cones to the edge of the larger cone, pointing in the same direction. Let the large cone swivel around a pencil or pen by holding it in the wind of the fan (see Sketch A).
2. Cut slits in the side of the plastic bottle and bend the flaps slightly outward. Make a small hole in the bottom of the bottle, turn it upside down on the stick and nail it loosely on the end of the stick so that the bottle can swivel easily (see Sketch B).
3. Color one of the small cones and one of the flaps of the plastic bottle red or black. To calibrate the instrument, hold it out a car window when the car moves with a speed of 20, 30, 40, 50 km/h and count the number of revolutions for each of the velocities (do this on a day when there is no wind blowing).

Questions:

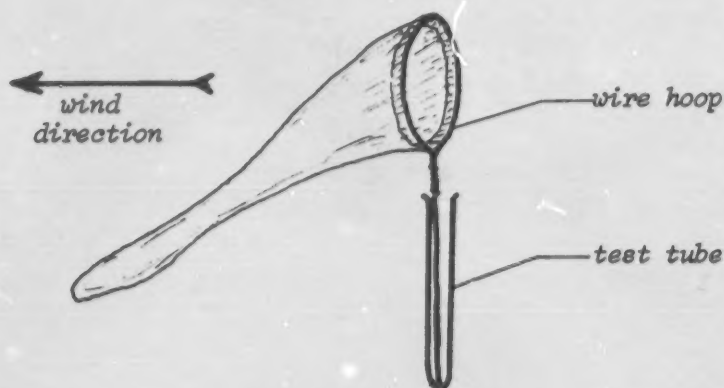
1. Will anemometer A turn in the same direction as B (see Sketch)?
2. How can we measure the wind speed with this anemometer?
3. Does it matter where the wind comes from when using this anemometer?
4. In calibrating the instrument, why do we have to wait for a day when there is no wind?
5. What makes the anemometer turn only in one direction?

Explanation:

The anemometers as shown in the sketch will turn in opposite directions. The simple anemometer turns only in one direction when held in a stream of air, because the air resistance on one side of the cone or cylinder is less than on the opposite side. After calibrating the instrument it is just a matter of counting the number of revolutions to tell how fast the wind blows. A day with no wind should be chosen to calibrate it, as the existing wind will otherwise affect the reading.

3.7. FIND WIND SPEED AND DIRECTION TOGETHER

- Materials:**
1. A nylon stocking & a medium size wire (about 80 cm).
 2. A narrow test tube & a small electric fan.



Procedure:

1. Make a hoop (circle) with a 10-15 cm diameter from one end of the wire, and let the other end protrude for at least 20 cm.
2. Fold the edge of the opening of the stocking around the hoop and tape it secure to the hoop.
3. Stick the protruding end of the wire into the test tube and make sure it can swivel freely in the tube.
4. Bring the "wind-anemo-vane" in the wind stream of the fan or place it outside in the ground on a windy day.

Questions:

1. What other material can be used instead of the stocking?
2. Why does the stocking turn away from the wind?
3. How can we tell the speed or velocity of the wind?
4. How would you calibrate this instrument?
5. What is a wind velocity meter called?
6. Why is the measuring of the wind speed important?
7. What do we need in order to forecast the weather?

Explanation:

The stocking or strips of paper in the wind will act just like a flag in the wind. It will wave away from the wind, similarly the stocking will point in the direction where the wind is going to and not where it is coming from. The windvane, on the other hand, is pointing into the wind, opposite to what the stocking is doing.

The stocking may be called a "wind-anemo-vane" because it does both: indicating the direction and the speed of the wind. The instrument measuring the speed of the wind is called: anemometer. The more horizontal the stocking, the stronger the wind is.

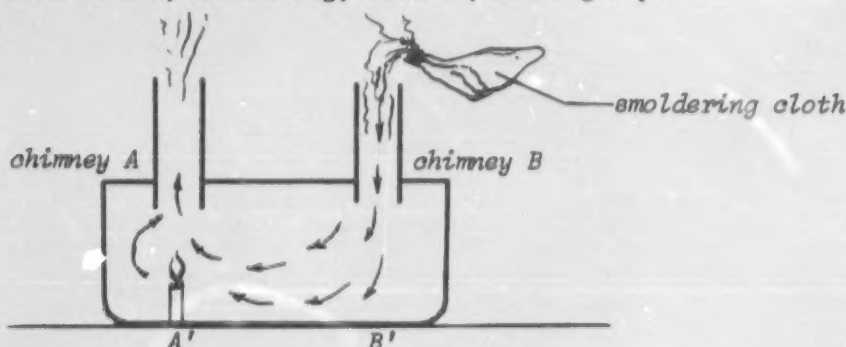
Measuring the wind speed and direction is very necessary in the forecasting of the weather.

WEATHER

WIND

3.8. CREATE WIND CURRENTS

- Materials:**
1. An empty aquarium or any large transparent container.
 2. Thin cardboard (bristol board or manila folders).
 3. Black bristol board or black carbon paper.
 4. A small candle, an old rag, matches, masking tape.

**Procedure:**

1. Make a cover for the aquarium with two holes, and also two fitting pipes, that will act as chimneys, from the thin cardboard.
2. Cover the backside of the container with black paper, so that the smoke currents can be more easily seen (use a spotlight if available).
3. Fix the candle under one of the holes in the bottom of the aquarium and light the candle.
4. Place the cover over the container and tape the edges airtight to it.
5. Make a smoke source from the rag (by burning it and letting it smolder) or light a cigaret, and hold the smoke close to chimney B (see Sketch).
6. Let the smoke fall into chimney B (do not hold the smoke source directly above the opening, but blow the smoke over the opening) and let the students observe the smoke currents.

Questions:

1. What makes the smoke fall in chimney B?
2. Why does the air rise through chimney A?
3. What is the purpose of the burning candle?
4. How can we create wind currents without the burning candle?
5. What places on earth can spot A' and B' be compared with?

Explanation:

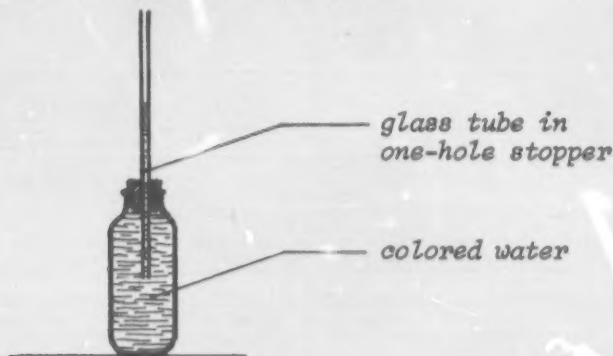
The burning candle is a source of heat. It heats the air above and around the flame, and heated air rises. This makes the air rise through chimney A, and because air goes out of the container, air must replace it, and this comes in through chimney B, taking the smoke with it. Spot A' can be compared with a hot place on earth (f.i. the tropics) and B' with a cold place (the poles). The air currents or winds are created this way between such places on earth. Instead of the candle we can also use an ice cube above chimney B. Cold air will move down and create the same currents.

WEATHER

TEMPERATURE

3.9. MAKE YOUR OWN THERMOMETER

- Materials:
1. A small soda-pop bottle & food coloring or ink.
 2. A transparent plastic straw or glass tube.
 3. A clump of clay or a one-hole stopper.
 4. An alcohol burner & stand, or a candle.

Procedure:

1. Fill the pop bottle full with cold water and color it with a few drops of food coloring or ink.
2. Put some clay around the straw or insert the glass tube in the one-hole stopper (make sure that only a short end will go in the bottle).
3. Immerse the straw or glass tube in the water-filled bottle, insert the stopper and mark off the water level in the straw or tube.
4. Heat the pop bottle or cool it down with an ice cube and let students observe the change in water level.

Questions:

1. Why does the straw or glass tube connection to the bottle have to be watertight?
2. What will heating or cooling do to the water level in the tube?
3. How similar is this instrument to a real thermometer?
4. How could we calibrate this simple instrument?
5. Could this instrument actually be used to measure temperatures?

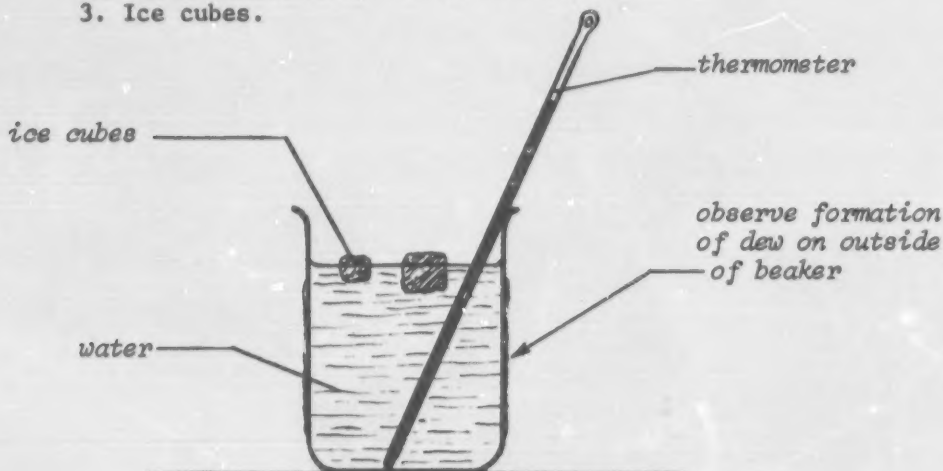
Explanation:

The small soda-pop bottle can be compared to the bulb of a regular thermometer. The larger this bulb, the more sensitive the thermometer is: thermometers for measuring body temperature have large bulbs and narrow tubes. Heating the bottle will result in heating the liquid and thus expanding it, causing the higher liquid level in the tube. Cooling the bottle causes the liquid to contract, resulting in a lower reading level. Calibrating of the bottle thermometer can be done by immersing the bottle in melting ice (0°C), marking the water level; then leaving the bottle at room temperature for some time (20°C), marking the water level in the tube, then dividing the space between the two marks by 20 for each degree Celsius.

WEATHER

DEW POINT
TEMPERATURE3.10. AT WHAT TEMPERATURE IS DEW FORMED?

- Materials:
1. A beaker or regular drinking glass.
 2. A thermometer (-5° to 50° or 100° C)
 3. Ice cubes.

Procedure:

1. Fill the beaker almost full with water and add a few ice cubes.
2. Keep track of the temperature of the mixture and observe carefully the outside of the beaker or glass.
3. Stir the mixture once a while with the thermometer (carefully) and note the temperature at which the dew is first formed on the outside of the glass (look for a dullness on the glass).

Questions:

1. Where does the dew on the outside of the glass come from?
2. At what temperature was the dew formed?
3. Is there always the same amount of water vapor in the air?
4. Will the dew point be higher or lower on humid days?
5. Where do we encounter a similar event inside the house in winter?

Explanation:

The ice cubes in the water are cooling the mixture slowly down and depending on how much moisture there is in the air, the sooner or later the water vapor will condense on the outside of the beaker; thus the higher or lower the dew point will be respectively.

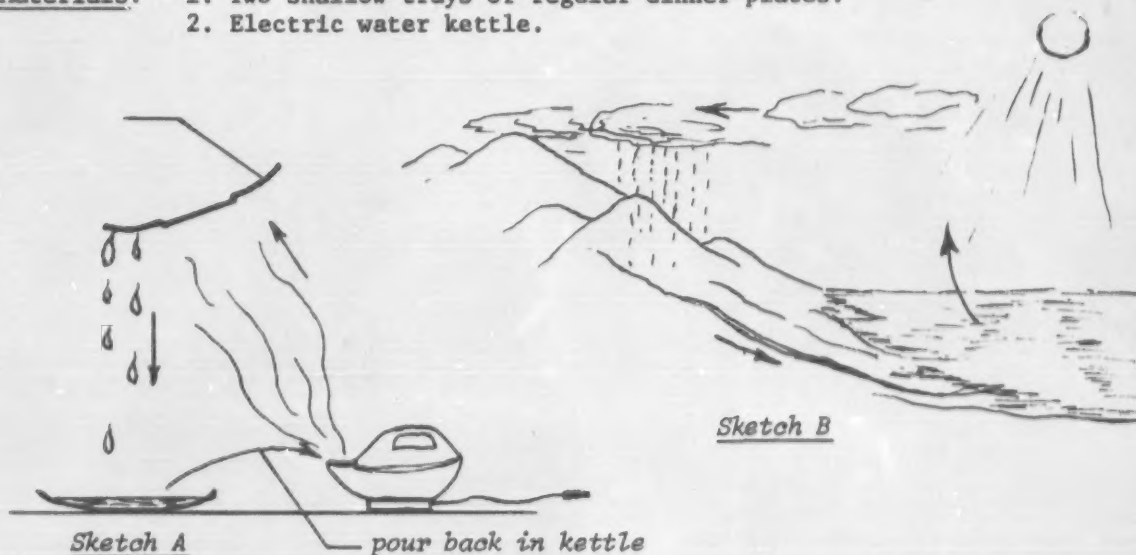
The drier the air around the beaker is, the lower the temperature has to be, before any water vapor will condense on the beaker's surface, and thus the lower the dew point.

Just after a rainfall the air is very humid, meaning that the percentage of water vapor in the air is high, and thus the dew point is also high. On dry days or in areas of low humidity, the temperature has to drop quite low before any dew drops are formed on the grass in the morning.

WEATHER

WATER CYCLE
TEMPERATURE3.11. RECYCLE THE WATER

- Materials:
1. Two shallow trays or regular dinner plates.
 2. Electric water kettle.

Procedure:

1. Heat water in a kettle until boiling.
2. Suspend a tray or plate in the steam or water vapor that comes from the kettle, and place the second plate under the first to catch the water drops (condensate). (Put cold water in the first plate).
3. Pour the water from the second plate back in the kettle to complete the cycle

Questions:

1. What made the steam or water vapor turn back into water?
2. Would the steam also condense if the top plate was filled with hot water?
3. What are conditions for clouds to turn into rain?
4. What makes the water evaporate in nature?
5. What can the pouring back of water from the lower plate into the Kettle be compared with in the natural water cycle?

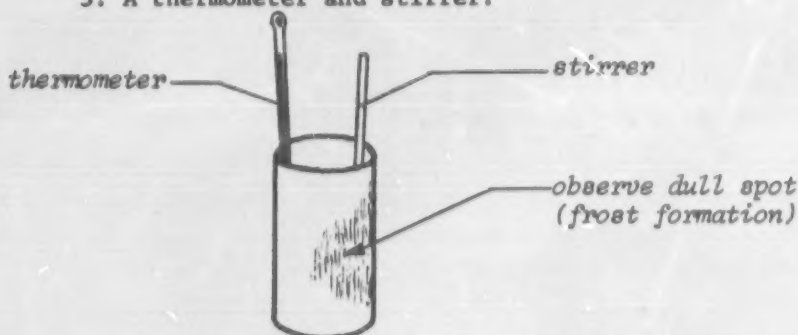
Explanation:

The steam or water vapor is produced in the kettle, because the water in the kettle is heated. When the steam hits the cold plate, it condenses back into water. The kettle can be compared to the ocean water being heated by the sun rays. The water vapor accumulates in the higher layers of the atmosphere to form clouds. When these clouds move into colder regions, they saturate the air with water vapor and the cold temperatures turn it into rain--condensation. This may be compared to the steam hitting the cold surface of the first plate. The rain water in nature flows into rivers and these flow back into the ocean (Sketch B).

WEATHER

FROST FORMATION
TEMPERATURE3.12. THE FROSTY CAN

- Materials:
1. A tin can (from which the label is taken off).
 2. Crushed ice & coarse table salt.
 3. A thermometer and stirrer.

Procedure:

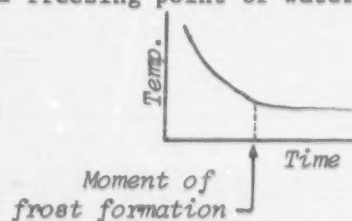
1. Fill the tin can, from which the label is taken off, with crushed ice and a handful of salt.
2. Place the thermometer in the can and stir with a separate stirrer.
3. Have students read off the temperature every half minute.
4. Have other students observe carefully the outside surface of the can and indicate to those observing the temperature, the moment that they observe frost formation (when the shiny surface gets dull).
5. A further extension of the activity might be the graphing of the data of observed temperatures and the time elapsed.

Questions:

1. What is the purpose of the salt mixed in with the crushed ice?
2. How low does the temperature inside the can have to be in order to form frost on the outside?
3. What do you expect the temperature of the ice and salt will do after the moment that frost is formed?
4. After observing the shape of the graph after frost formation, what is the process of frost formation doing: absorbing or giving off heat?
5. Where does the frost come from; what is needed in the air?

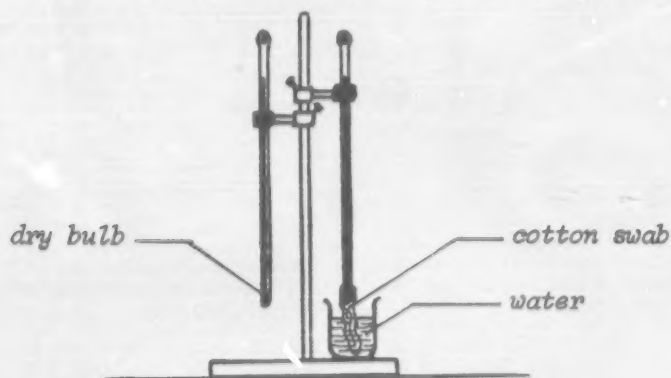
Explanation:

The salt in the crushed ice makes the ice melt in the beginning, but brings the temperature down below the normal freezing point of water (0°C). The moisture in the air, hitting the cold surface of the can, turns into the solid state (frost) without passing the liquid state: sublimation. This process, just like condensation, is giving off heat, which is why the graph levels off after frost formation (see Graph on the right).



3.13. THE WET AND DRY THERMOMETER

- Materials:
1. Two identical thermometers.
 2. A small swab of absorbent cotton, or piece of cotton cloth.
 3. A small beaker, two clamps and stand.



Procedure:

1. Clamp two thermometers close to each other on one stand.
2. Have students read off both temperatures.
3. Wrap one thermometer bulb with a small swab of absorbent cotton.
4. Place some water in the small beaker and keep the cotton around the bulb wet at all times.
5. Have students read off both temperatures again.
6. Determine the relative humidity from the humidity chart.

Questions:

1. Why is there a difference between the dry and the wet bulb temperature?
2. What causes the wet bulb temperature to decrease?
3. What effect does a higher relative humidity have on the difference between wet and dry bulb temperatures?
4. What can we say about the relative humidity when the difference between the two temperatures is large?
5. What can we say about the relative humidity when the difference between the two temperatures is small?

Explanation:

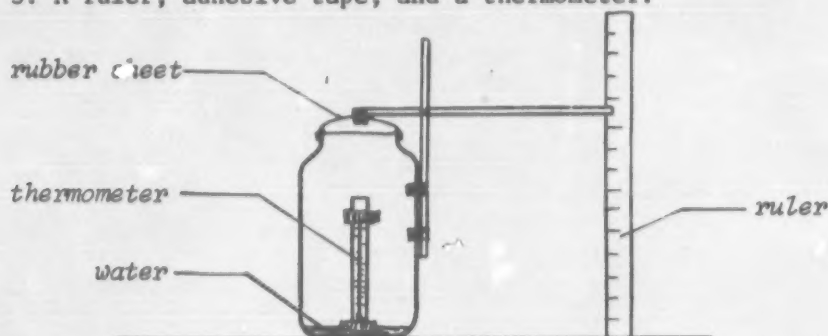
The wet bulb temperature decreases, because the evaporating water withdraws heat from its environment. The drier the atmosphere is, the faster the water will evaporate, and thus the lower this wet bulb temperature gets, resulting in a greater difference between the two temperatures. When the relative humidity is high, the dry bulb can almost be considered to be a wet bulb; also the rate of evaporation of the water is much slower, because the air is almost saturated with water vapor. A smaller difference between the two temperatures therefore indicates a high relative humidity (see Humidity Chart in Appendix).

WEATHER

HUMIDITY

3.14. THE JAR HYGROMETER

- Materials:
1. A wide-mouth gallon jar (pickle jar).
 2. A large balloon, 2 drinking straws, a straight pin.
 3. A ruler, adhesive tape, and a thermometer.

Procedure:

1. Place a few millilitres of water in the jar.
2. Blow up the balloon (preferably a day or a few hours before use), so that the rubber is stretched.
3. Cut a piece off the stretched balloon (large enough to cover the jar opening) and tape it airtight to the jar mouth.
4. Tape two straws pivoted with a pin to the center of the rubber sheet and to the side of the jar (see Sketch).
5. Place the jar such that the straw indicator points along a ruler.
6. Place a thermometer close to or tape it to the jar, and read the humidity off the ruler at the same temperature, twice a day

Questions:

1. When the humidity gets lower, will the reading on the ruler be higher or lower?
2. What is the relative humidity inside the jar?
3. What is the absolute humidity as compared to the relative humidity?
4. How will an increase in temperature affect the relative humidity reading on this instrument?
5. What is a most comfortable relative humidity to maintain?
6. How can we increase the humidity in our homes in the winter?

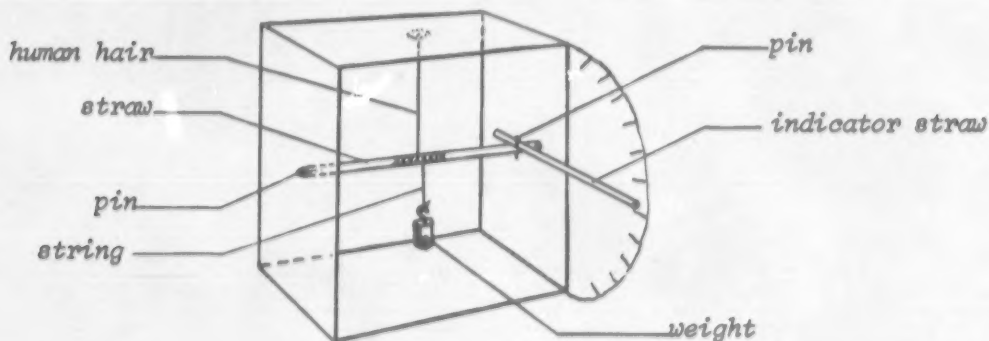
Explanation:

The hygrometer only measures the relative humidity in the air. The absolute humidity is the actual amount of water vapor that the air holds at a particular temperature. The presence of the water in the jar makes the relative humidity 100%. This means that the air inside the jar cannot hold more water vapor: it is saturated with water vapor. This miniature atmosphere is being compared with the outside atmosphere. The less humidity in the atmosphere, the more the rubber diaphragm will bulge up, and thus the lower the reading. The term *relative* comes from this comparison with the maximum capacity of the air in holding water vapor.

A comfortable relative humidity is about 60 - 70%.

3.15. THE HAIR HYGROMETER

- Materials:
1. A wooden cigar box, 2 drinking straws, pins.
 2. A long human hair, string, and a weight (20 g).

Procedure:

1. Attach a long human hair to the center of the topside of the box, and wind the other end around a horizontally rolling straw, turning freely around pins at each end (see Sketch) and tape the end of the hair to the straw.
2. Now tape a string or thread to the same straw and wind it such that the weight on the other end of the string will pull the hair straight.
3. Attach another straw perpendicular to the first one with a pin or tape. Attach a semi-circle cardboard to the side of the box closest to the indicator straw (draw some graduations on the edge of the semi-circle beforehand (see Sketch)).
4. Read off the relative humidity (position of the indicator straw) and compare with readings announced on the radio.

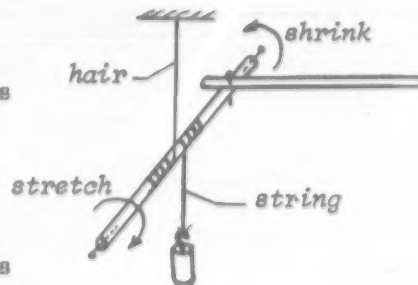
Questions:

1. What does more or less humidity do to human hair?
2. Does higher humidity cause the indicator straw to go down or up?
3. What is the purpose of the weight?
4. How can we calibrate this instrument?

Explanation:

Human hair stretches when the air is humid and it shrinks when the air is dry. The weight just keeps the hair tight, thus when the hair stretches, the horizontal straw turns clockwise, and the indicator tip lowers. Lower humidity in the air causes it to move up higher.

Calibrating of this instrument may be done by listening to radio weather reports and assigning the appropriate values to the graduations.

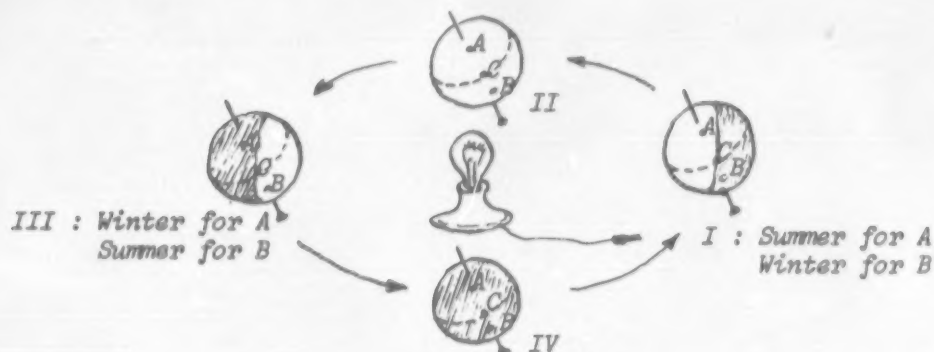


WEATHER

CLIMATE

3.16. WHY LONGER OR SHORTER DAYS?

- Materials:
1. A regular glowing light bulb or strong flashlight.
 2. A medium size smooth rubber ball.
 3. A knitting pin and marker.

Procedure:

1. Stick the knitting pin through the center of the ball and light the bulb.
2. Hold the ball and knitting pin slanted to the left (top towards the light) at position I; and let the ball spin slowly around the pin.
3. Point out to the students spot A, B, and C (marked on the ball with a marker). Ask: "Which spot gets the most light?"
4. Sequentially, move the position of the ball globe from I to II, to III, and to position IV, and spin the ball around the pin as axis.

Questions:

1. At what position is it summer for place A on the globe?
2. At what position is it spring, winter, and fall for place A?
3. What makes the days longer in the summer for North Americans?
4. Why does the sun always set at 6 p.m. in a tropical country throughout the whole year?
5. Which point represents a tropical country on our globe?

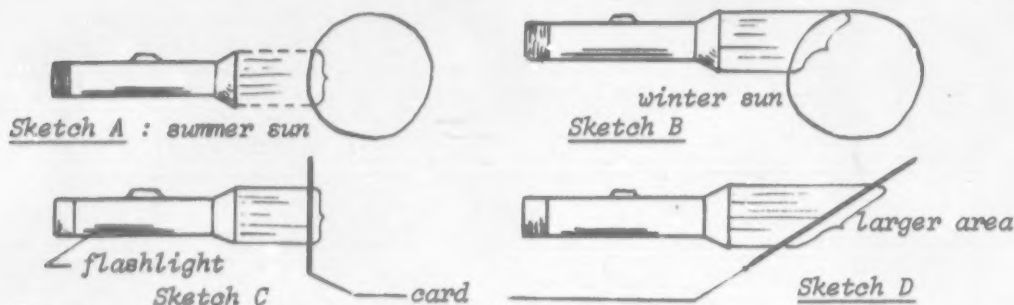
Explanation:

The bulb represents the sun and the ball the earth with the knitting pin as the earth's axle (the poles). This axle, around which the earth is rotating, is not perpendicular to the plane in which the earth revolves around the sun. This slanted axle is the reason why we have four seasons in North America, Australia, and countries at about equal latitudes.

One turn around the axis represents one day and one revolution around the light represents one year. The difference between point A and B should especially be pointed out, at the moment that the shadow reaches one of them when the globe is being spun around its axis. Position I represents summer time, II autumn, III winter, and IV spring for spot A on earth; and winter, spring, summer, and fall respectively for spot B.

3.17. THE COOL WINTER SUN

- Materials:
1. A large smooth ball (without any designs).
 2. A strong flashlight, a paper card or white cardboard.

Procedure:

1. Shine the flashlight to the center of the ball (Sketch A), then shine it to the edge (Sketch B) and compare the brightness of the light spots.
2. The earth's surface in summer and winter may be compared with the positions of the card. Hold the card perpendicular to the light rays (C) and slant it away from the flashlight (Sketch D).
3. Let students observe the intensity of the light spot on the card.

Questions:

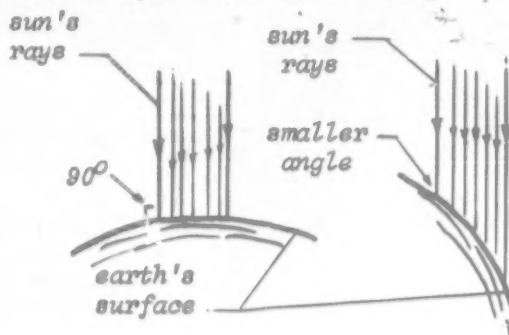
1. Which position of the ball or card shows the light less bright?
2. What is different between position A & B, or C & D?
3. Which of the positions has more surface area illuminated?
4. Was the amount of light changed to illuminate more surface area?

Explanation:

When the sun's rays strike the earth perpendicular to the surface, they are hotter compared to when they strike the earth in a smaller angle. This is because the same amount of sun is spread out over a larger area. The intensity per square area is thus diminished.

The sun's rays in the summer are striking the earth's surface very similarly as the sun's rays strike the tropical areas on earth (perpendicular). The angle of the sun's rays striking the earth in winter may be compared with the angle of the sun's rays and the earth at sunset.

Although the sun's rays and their number do not change, their intensity is always much less at sunrise or during sunset.



CHAPTER 4

WHAT ARE THE CHARACTERISTICS OF MATTER ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts of this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

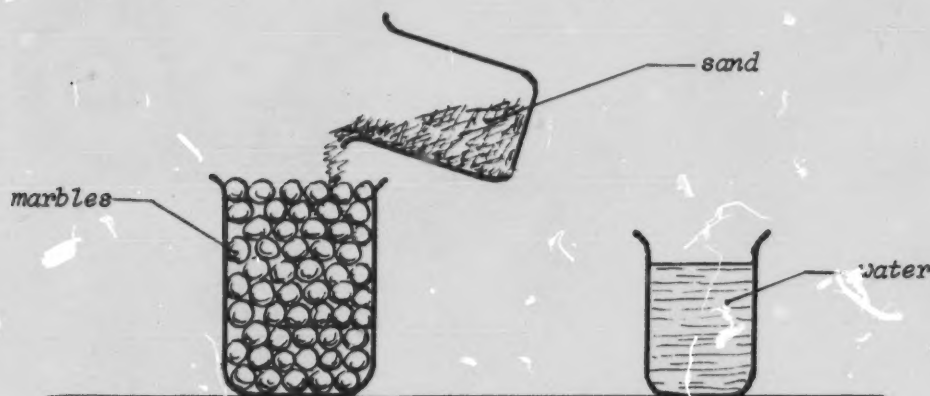
- Between the molecules of matter there exists space.
- Matter exists in three states: solid, liquid, and gas.
- Melting and boiling points are specific for pure substances.
- Cohesion is a force that keeps like molecules attracted to each other.
- Adhesion is a force that keeps unlike molecules attracted to each other.
- Surface tension exists at the surface of a liquid.
- Density is characteristic for different materials.

CHARACTERISTICS OF MATTER

MOLECULAR SPACING

4.1. CAN THE CONTAINER HOLD MORE?

Materials: 1. A transparent container (glass or plastic).
2. Marbles, sand and water & a graduated beaker.



Procedure:

1. Fill the transparent container up to the brim with marbles.
2. Show the students that you still have sand and water; ask them: "Can I add any other material to this container?"
3. Add sand to the container (shake to settle the sand in between the marbles); ask the same question again.
4. Now add water to the mixture of water and sand.
5. Measure off the amount of sand and water added to the marbles (by measuring how much is left over in a graduated beaker).
6. Do not neglect to tell students that the marbles, sand, and water particles are only illustrating how molecules of matter are behaving and that they are not molecules themselves! It is only a model!

Questions:

1. Why could the container that was already filled with marbles still hold more sand and water?
2. Could we have started with water, then sand and marbles?
3. What would you infer that the sizes of molecules of different materials or substances would be?
4. What other materials could be used to do this demonstration?

Explanation:

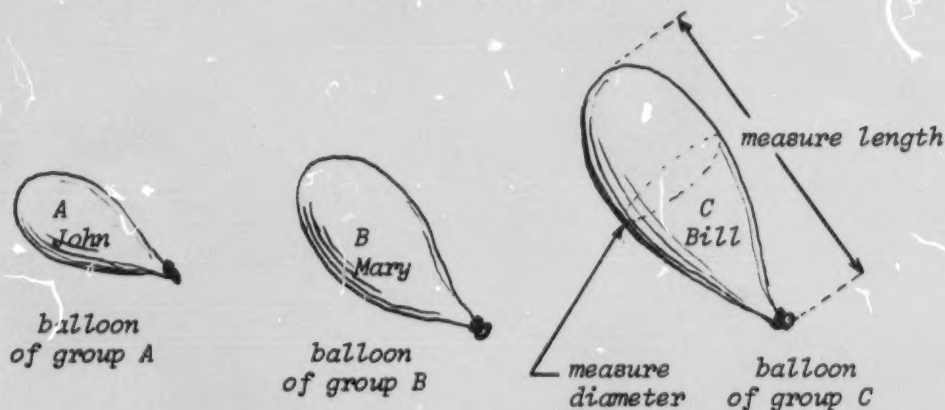
The marbles, sand and water particles are used only as an analogy of how molecules of different sizes would behave. The smaller sized molecules can slip in between the larger ones. Thus it is possible to slip the sand or the water in between the marbles, but not the other way around. It is especially important to point out to students, that the marbles or sand grains are not molecules, but that molecules are so small that we cannot see them, not even with a microscope.

CHARACTERISTICS OF MATTER

MOLECULAR SPACING

4.2. THE SHRINKING BALLOON

- Materials:**
1. A balloon for each of the students.
 2. Flexible measuring tapes or string and meter sticks.



Procedure:

1. Divide the class into three groups A, B, and C; distribute the balloons.
2. Have group A blow the balloon up and let about half the amount of air out, group B blow the balloon up and then let about $\frac{1}{2}$ of the air out, and have group C leave the balloon blown up fully, and tie a knot in it.
3. Have each student measure the diameter and length of his or her balloon with the measuring tape or place a length of string around the balloon and measure the string with a meter stick.
4. Let each student record these measurements and mark their balloons with their names, and put them away for the next day (they could be placed in cupboards or stuck to the walls).
5. The next day, have students measure the diameter and length of their balloons and compare these with those of the day before.

Questions:

1. What made the balloon shrink in size?
2. Which of the three groups had the fastest shrinking balloon?
3. Were there any leaks in the balloons?
4. What would the balloon do if kept for another day?
5. Where do we find applications of this principle in daily life?

Explanation:

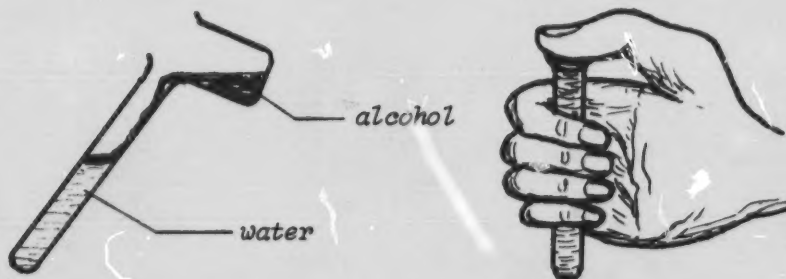
The air molecules in the balloon are much smaller in size than the rubber molecules of the balloon itself. Although many layers of rubber molecules are contained in the balloon membrane, the tiny air molecules can slowly slip through these bigger ones that hold them inside the balloon. As the pressure inside is larger than outside, the air molecules move faster inside and push through the rubber. Over time, so many air molecules diffuse through the rubber that the pressure inside decreases, thus decreasing the size of the balloon. The rate of losing air molecules is greater for the larger balloon, because of the higher pressure.

CHARACTERISTICS OF MATTER

MOLECULAR SPACING

4.3. THE SHRINKING MIXTURE OF LIQUIDS

- Materials:
1. A test tube and small beaker.
 2. Alcohol - ethyl-, methyl-, or isopropyl-alcohol (methyl hydrate or rubbing alcohol may be used).



Procedure:

1. Fill the test tube half way with water.
2. Hold this test tube slanted and pour the alcohol slowly from a beaker until brim full.
3. Hold the test tube and place your thumb on the mouth of the tube, making sure that no air bubble is trapped.
4. Show the students that the tube is completely full.
5. Invert the tube several times (keep thumb on opening of test tube at all times; do not release the pressure).
6. Show to students that now the liquid level is lowered.

Questions:

1. Did the alcohol or water evaporate?
2. Was there any liquid spilled by inverting the tube?
3. Did the liquid shrink or contract?
4. Was there space between the water and alcohol molecules?

Explanation:

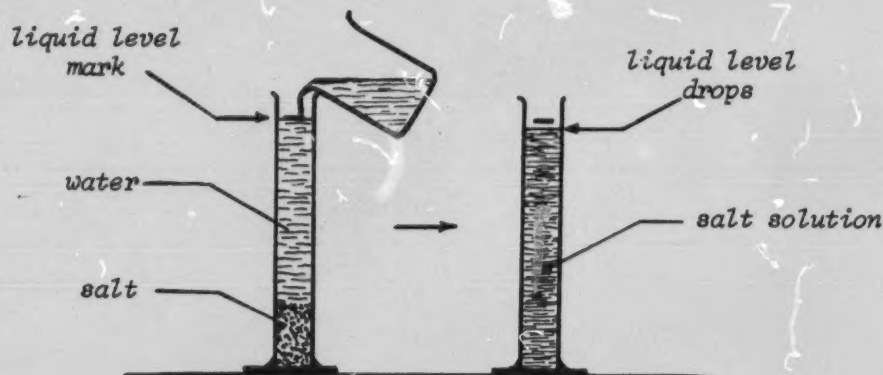
By closing the opening of the test tube tightly with the thumb, and not taking it off while inverting, no evaporation or spilling of the liquid could occur. By inverting the test tube, mixing of water and alcohol takes place, and because there are spaces between the molecules, the alcohol molecules slip in between the water molecules, thus making the total volume of the mixture become less. Although the spaces between the molecules cannot be seen by the naked eye, this demonstration shows that there must be room between the molecules. If ethyl alcohol is not available, methyl-hydrate (methyl alcohol) or rubbing alcohol (isopropyl alcohol) can be easily obtained from a drug store, and may replace it.

CHARACTERISTICS OF MATTER

MOLECULAR SPACING

4.4. IS THE CONTAINER LEAKING?

- Materials:
1. Water softener salt pellets or table salt.
 2. A graduated cylinder and a beaker.



Procedure:

1. Fill the cylinder 1/3 full with water softener salt pellets or with table salt.
2. Add water until full and mark the liquid level with a grease pencil or tape or rubberband.
3. Let it stand for a few minutes and observe liquid level.

Questions:

1. Where did the water go?
2. Is the cylinder leaking any water?
3. What do the salt molecules do when they dissolve?
4. Can we use other salts to do this demonstration?
5. Can sugar be used to do this same demonstration?

Explanation:

Students might incorrectly infer that the water is absorbed by the salt. As a follow-up to a response like this you might pour out the water before all the salt is dissolved and re-fill it with fresh water: the water level will drop again! The main cause of the water level dropping is, that the salt molecules break down into ions: NaCl molecules into Na^+ and Cl^- ions, which are much smaller than the molecules, and these ions can slip in between the water molecules. This makes the total volume decrease. Other salts that dissolve in water will exhibit the same property. Most inorganic water-soluble salts will do this. The sugar molecule is large in size and does not ionize when dissolved in water, so that the water level will stay at about the same spot when sugar is used.

This demonstration shows students that there are spaces in existence between water molecules that are not detected by the naked eye.

CHARACTERISTICS OF MATTER

STATES OF MATTER

4.5. THE VANISHING ICE CUBES

- Materials:**
1. A bag of ice cubes (3-4 cubes per pair of students).
 2. A thermometer, beaker, alcohol burner and stand (for each pair).
 3. Graph paper for all students.



Procedure:

1. Distribute the materials to the students and have them work in pairs.
2. Have one student stir the ice-water mixture and another one observe the temperature every minute while it is being heated (a third student may record the temperature called out).
3. After all the ice is melted, have the students keep on heating the water and record the temperature every minute until the water boils for about ten minutes.
4. Have the students plot the observed temperatures (Y axis) against the time (X axis) on a graph.

Questions:

1. What was the temperature doing while there was still ice present?
2. Where did the heat from the alcohol flame go during that time?
3. What did the temperature do while the water was boiling?
4. Where did the heat from the flame go during this boiling time?
5. What will eventually be left over if the boiling was continued?
6. When heat is not added to the melting process, what will the melting ice do to the environment?
7. When heat is not added to the evaporating process, what will water that is evaporating do to the environment?

Explanation:

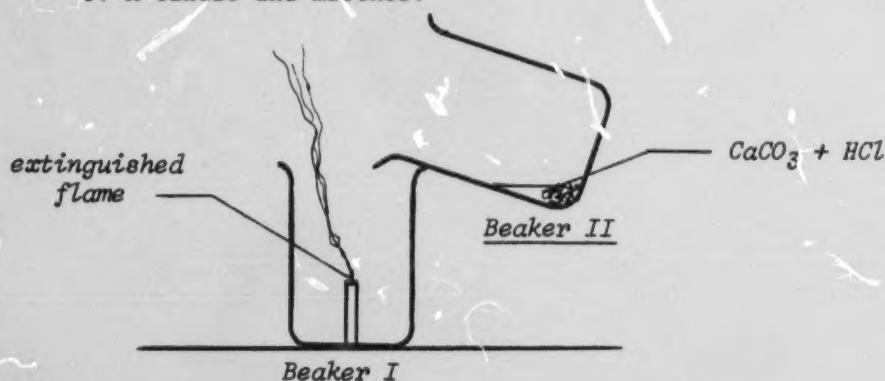
In the beginning of the heating process, the heat was used to melt the ice. This is why the temperature stayed at 0°C . This remains at that temperature as long as there is still ice present. As soon as all the ice is melted, the temperature rises steadily till 100°C , then it levels off and stays at the boiling temperature until all the water is evaporated (this temperature may be close to 98°C depending on the elevation of the place). The heat during the boiling process is used to transfer the liquid into the vapor state.

CHARACTERISTICS OF MATTER

STATES OF MATTER

4.6. THE INVISIBLE FLAME EXTINGUISHER

- Materials:
1. Two beakers (300 ml) (transparent plastic cups will do).
 2. Marble chips and hydrochloric acid (HCl) or carbontetrachloride (CCl_4).
 3. A candle and matches.



Procedure:

1. Secure the candle in the center of one of the beakers.
2. Put a teaspoon full of marble chips (calcium carbonate) in the other beaker and pour a few drops of dilute HCl on it, or pour a little carbontetrachloride (CCl_4) in the beaker.
3. Light the candle in the first beaker and pour the gas that has developed in the second beaker in the first (see Sketch): the flame will be extinguished.
4. To repeat the lighting of the candle, the air has to be replenished by inverting the beaker and holding it upside down for a while, then the candle can be lit and the gas poured to extinguish it again.

Questions:

1. What was it that extinguished the candle flame?
2. What gas was formed in the second beaker?
3. Could we observe the gas pouring down into the first beaker?
4. Why does the first beaker have to be inverted to replenish the air?
5. What are other invisible gases that you can name?

Explanation:

The gas formed in the second beaker is carbon dioxide (or CCl_4 vapor). By adding dilute hydrochloric acid to marble chips, we get the following reaction: $2 \text{HCl} + \text{CaCO}_3 = \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$

Carbon dioxide is an invisible gas (and so is carbontetrachloride vapor), which is heavier than air, and which has the property of extinguishing flames. The fact that it is heavier than air makes it possible to pour the gas from one container into the other. This is also why it is necessary to invert the first container to replenish the air.

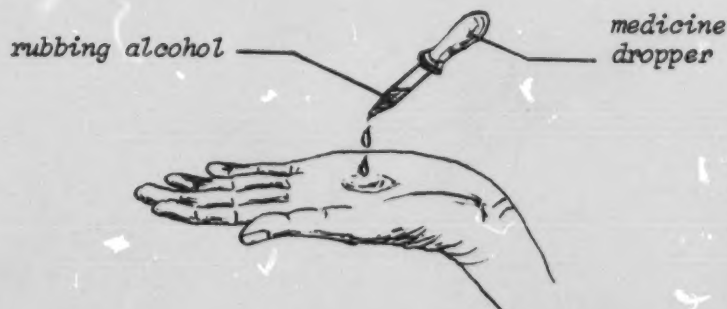
By using carbontetrachloride vapor we can make the illusion that an empty beaker is extinguishing the candle flame (by concealing the pouring of a few drops of the liquid in the second beaker from the students).

CHARACTERISTICS OF MATTER

STATES OF MATTER

4.7. THE DISAPPEARING LIQUID

- Materials:
1. A medicine dropper & wall clock or watches.
 2. Rubbing alcohol (isopropyl alcohol) or methyl hydrate.



Procedure:

1. Have each of the students stretch out one of their hands with the palm facing up and held horizontally.
2. Come around with the 'colorless liquid' and the dropper; place 3-4 drops on each of the palms.
3. Have the students measure the time it takes for the liquid to evaporate completely.
4. You may repeat the activity, but this time have the students race to evaporate the liquid as fast as possible. They may do everything to the liquid except removing it from the palm or applying a match to it. Some may try blowing, spreading it, etc.

Questions:

1. Where did the liquid disappear to?
2. What did you observe during the evaporation process?
3. How long did it take for three drops to evaporate?
4. Which method proved to be most effective to speed up evaporation?
5. Where did the energy to change the liquid into a gas come from?

Explanation:

As alcohol is very volatile, it evaporates quickly. The three drops on the palm evaporate within a few minutes. The transfer of a liquid into its vapor state takes energy. This energy is usually supplied to the liquid in the form of heat. When this heat is not supplied to the liquid, and it evaporates by itself, it withdraws the heat from its environment. This is why the palm feels cool.

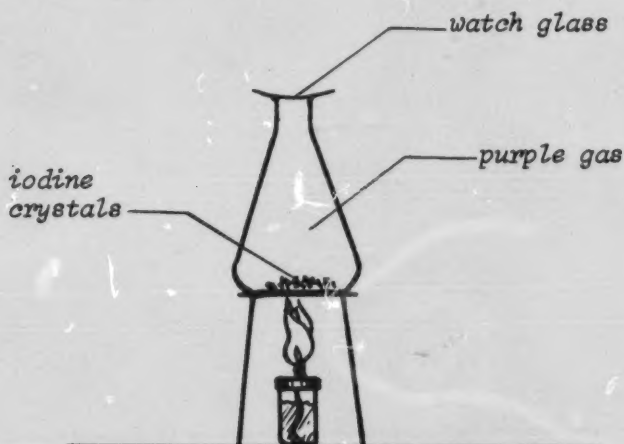
The evaporation process can be speeded up by blowing over the liquid, making the surface area larger by spreading it over the whole palm; doing both at the same time would probably be most efficient. Blowing warm air over the liquid would most likely increase the rate of evaporation.

CHARACTERISTICS
OF MATTER

STATES OF MATTER

4.8. MAKE A PURPLE GAS

- Materials:
1. An Erlenmeyer flask & small watch glass.
 2. Alcohol burner and stand.

Procedure:

1. Place a few iodine crystals in the Erlenmeyer flask and cover the opening of the flask with the watchglass.
2. Warm the crystals slowly over a small flame, and observe the flask.

Questions:

1. Did the solid iodine crystals melt by heating?
2. What is the process called when a solid changes directly into gas?
3. Is this process also reversible? Changing gas into solid?
4. What is needed to change gas into liquid or solid?
5. Where do we find gas to solid change in our daily life?

Explanation:

The iodine crystals, when heated, change directly into the gaseous state, and this process is called *sublimation*. When the purple iodine gas hits the cold surface of the flask or watchglass, it will sublimate back to the solid state. When we leave the alcohol flame on for a few minutes and then leave it to cool till the purple color starts to fade, we can see very tiny crystals forming on the cold glass surfaces of the upper part of the flask and the watchglass.

Do not lift the watchglass while the heating is taking place, as the iodine vapor is not fit to inhale. Keep the watchglass on the flask at all times to prevent the iodine fumes from escaping.

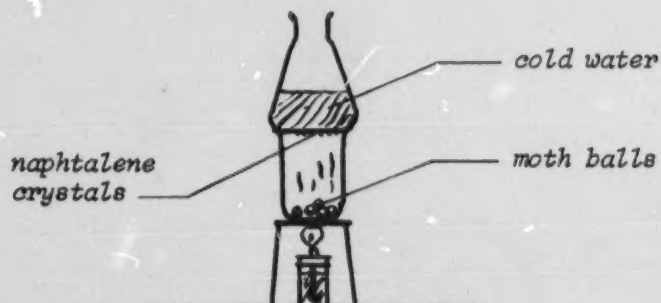
Sublimation from gas into solid in our daily life occurs when a freezer door is accidentally left open. Water vapor in the air hits the cold surface of the freezer and immediately turns into solid without passing the liquid state: the frost found in the freezer compartment.

CHARACTERISTICS OF MATTER

STATES OF MATTER

4.9. CHANGING GAS INTO CRYSTALS

- Materials:**
1. A medium size beaker.
 2. Erlenmeyer flask or beaker with a larger base than beaker No. 1.
 3. Alcohol burner and stand, moth balls.



Procedure:

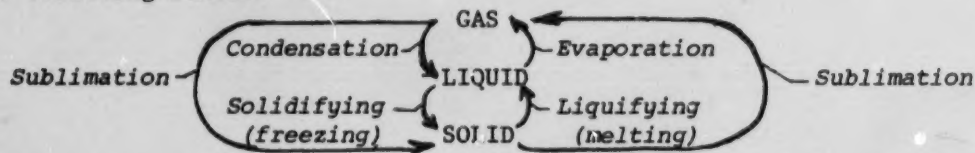
1. Place 4 or 5 moth balls or a scoop of flakes in the beaker and heat it slowly over a small flame.
2. Fill the flask halfway with cold water and stack the flask on top of the beaker holding the moth balls.
3. Leave the alcohol burner on until all the moth balls are melted, then blow the flame out and leave the flask on top of the beaker for another 5-10 minutes. (a longer time is even better).
4. Lift the flask carefully and slant the bottom towards the students to show the crystals.

Questions:

1. What is the process of solid to liquid change called?
2. What is the process of solid to gas change called?
3. What is the process of gas to solid change called?
4. Where does the solid to gas change occur in daily life?
5. What purpose does the cold water have in the flask?
6. What other material behaves like the moth balls when heated?

Explanation:

By heating the moth balls, they change from solid into liquid state and also into the gaseous state directly. This first process is called *melting* or *liquifying* and the second is *sublimation*. Other processes are named in the following scheme:



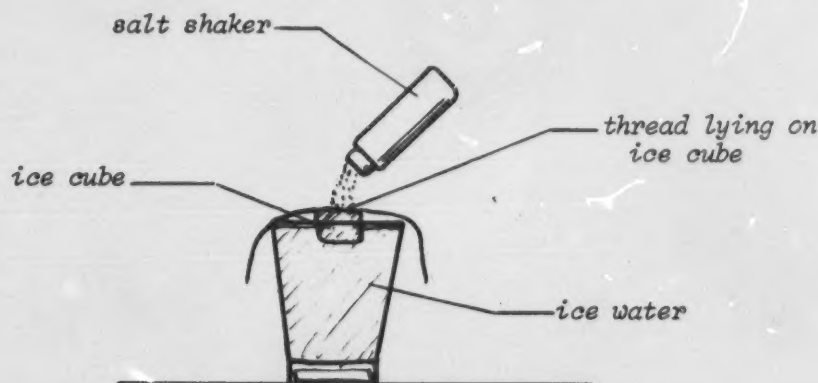
Other materials that sublime like moth balls are sulfur (found in craters of volcanoes), iodine, and ice.

CHARACTERISTICS OF MATTER

MELTING POINT

4.10. LIFT AN ICE CUBE WITH SALT

- Materials:
1. An ice cube floating in cold water in a cup.
 2. A sewing thread and salt shaker.



Procedure:

1. Let an ice cube float in a full cup with cold water.
2. Show students the salt shaker and the thread and ask: "How can I lift the ice cube out of the water without getting under the cube?"
3. Let the thread lie on the ice cube and sprinkle salt on it--especially close to the thread.
4. Wait a minute or so, lift the thread slowly to check whether the water above it has frozen; if so, lift both ends of the thread and lift the ice cube out of the water.

Questions:

1. What does salt do to ice on the road in the winter time?
2. At what temperature does ice melt?
3. What do you think salt does to the melting point of ice?
4. What must the melted ice above the string do in order to lift the cube?
5. Where else do we find this principle of lowering the melting point of ice applied in daily life?

Explanation:

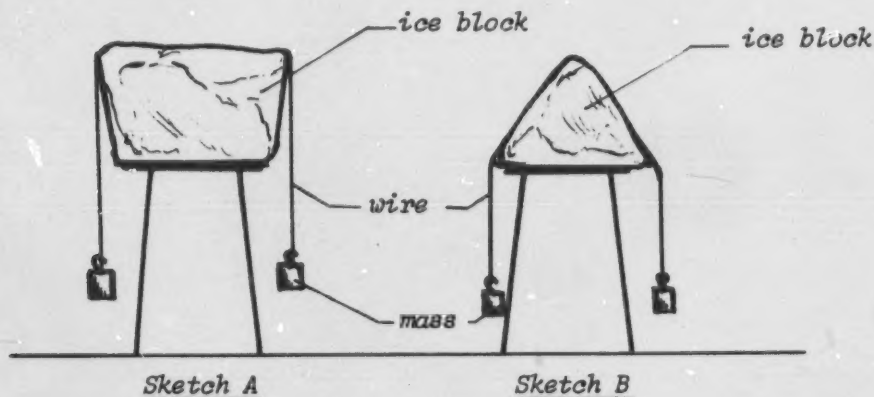
As salt water has a lower melting or freezing point than pure water, the addition of salt to the ice cube makes it melt at the places where the salt is sprinkled. This means that the ice around the thread will melt, but the temperature of this water above the ice cube is still below 0°C . When the salt dissolves in more of the melted ice, the solution gets more dilute, increasing the freezing point close to 0°C . As this water still has a temperature of a few degrees below 0°C , it freezes again. This makes it possible to lift the ice cube out of the water. When making ice cream at home, crushed ice and salt are mixed in the mantle of the ice-cream maker to lower the temperature below the freezing point of water.

CHARACTERISTICS OF MATTER

MELTING POINT

4.11. CUT THROUGH ICE WITH A WIRE

- Materials:
1. A rather large ice block.
 2. An iron or copper wire (about 1 m long).
 3. Two 1 kg weights or large rocks, tripod or tall tin can.



Procedure:

1. Place the ice block on the stand or on a tall tin can such that the ice block overhangs the edge of the can (the ice block should be larger in diameter than the can or tripod).
2. Tie the wire ends to the weights and hang it over the ice block, such that the weights are hanging freely (see Sketch).
3. Leave the wire hanging for a while and observe the top part of the ice block on which the wire rests (hang heavier weights on the wire to speed up the process).

Questions:

1. Why does the wire cut into the ice?
2. What happened to the water above the wire?
3. What property is being lowered by increasing the temperature?
4. Would a smaller ice block be cut faster?
5. Would larger weights cut the ice block faster?
6. Will the wire cut faster through block A or B? (see Sketch)

Explanation:

Under high pressure the melting point of solids gets lowered. Under the wire, the ice molecules are pressed and thus they move faster. Immediately under the wire then, we get faster moving molecules, thus higher temperatures and melting of the ice. The wire moves through this water, but as soon as that water gets above the wire, the pressure is off and the temperature of the water gets below 0°C and it freezes again.

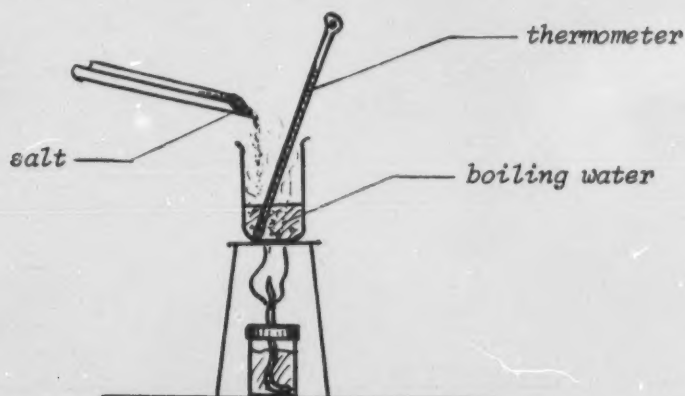
The larger the weights, the higher the pressure on the ice, and thus the faster the temperature under the wire is raised. This increases the rate at which the wire cuts through the ice. The same thing happens when the size of the ice block or the surface area between the wire and the ice is reduced (Sketch B).

CHARACTERISTICS OF MATTER

BOILING POINT

4.12. HEAT WATER ABOVE ITS BOILING POINT

- Materials:
1. A small beaker (100 ml) & thermometer.
 2. A burner and stand.
 3. Table salt (sodium chloride).



Procedure:

1. Let students work in pairs. Distribute the above materials to each pair of students.
2. Heat about 20 ml of water, place the thermometer in the beaker and record the temperature every half minute (one student stirs with the thermometer and reads off the temperature while the other records it).
3. As soon as the water boils, let students add different amounts of salt to the water (2, 4, and 6 g of salt could be given to three groups of student pairs).
4. Continue heating, stirring, observing the temperature, and recording it every half minute until the water boils again.

Questions:

1. What happened to the boiling when the salt was added?
2. What happened to the temperature after the salt was added?
3. What is the normal boiling point of water?
4. Which of the three groups had the highest boiling point?

Explanation:

As soon as the salt is added to the boiling water, the temperature drops and the water stops boiling. This is because the salt has a lower temperature and dissolving it in the water absorbed some of the heat. With the salt in the water, the water molecules adhere not only to each other--*adhesion*, but also to the salt ions, which makes it harder to transfer the water into the gaseous state. This is why the water has to have a higher temperature to boil. The more salt, the higher the boiling temperature of the solution, but the temperature of the water vapor stays at 100° C (this can be checked by lifting the thermometer above the liquid).

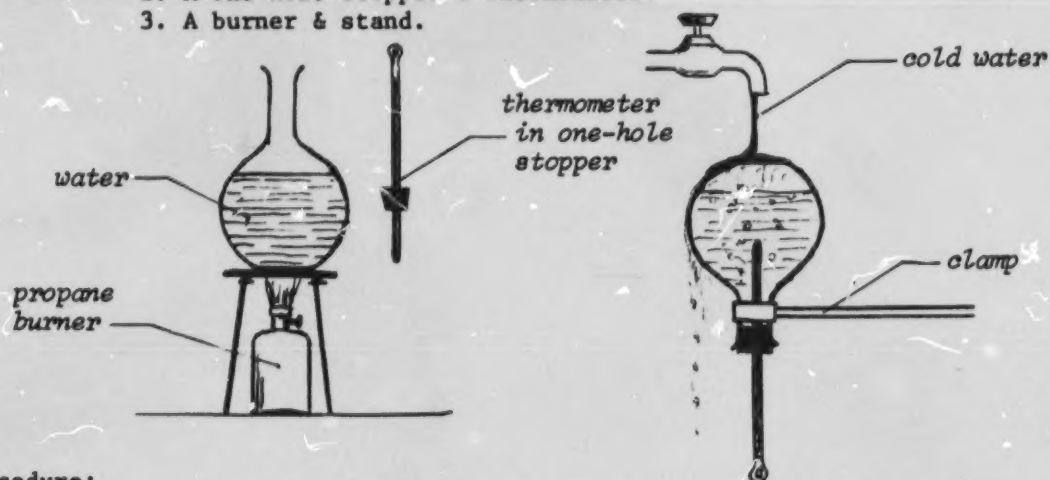
This demonstration shows that impure water (water that contains minerals and salts) has a higher boiling point than pure (distilled) water.

CHARACTERISTICS OF MATTER

BOILING POINT

4.13. BOIL WATER WITH COLD WATER

- Materials:**
1. A round or flat bottom flask, clamp, boiling chips.
 2. A one-hole stopper & thermometer.
 3. A burner & stand.



Procedure:

1. Fill the flask 3/4 full with water, put a few boiling chips in it, and heat over the burner and stand until boiling.
2. Attach clamp on flask's neck, shut flame off and immediately close flask with the one-hole stopper with the thermometer in it, and have a student read off the temperature (should be about 98°-100° C).
3. Invert the flask and hold it under a cold stream of water from the tap above a sink, or wipe the bottom of the flask with a towel soaked in cold water.
4. Observe boiling water and have students read off the temperature.

Questions:

1. Why does the water stop boiling after the heat is taken away?
2. At what temperature does water boil at normal pressure?
3. What is the cold water doing to the water vapor in the flask?
4. What do you think the pressure above the water in the cooled flask is?
5. What is the lowest temperature at which the water is still able to boil in the cooled flask?

Explanation:

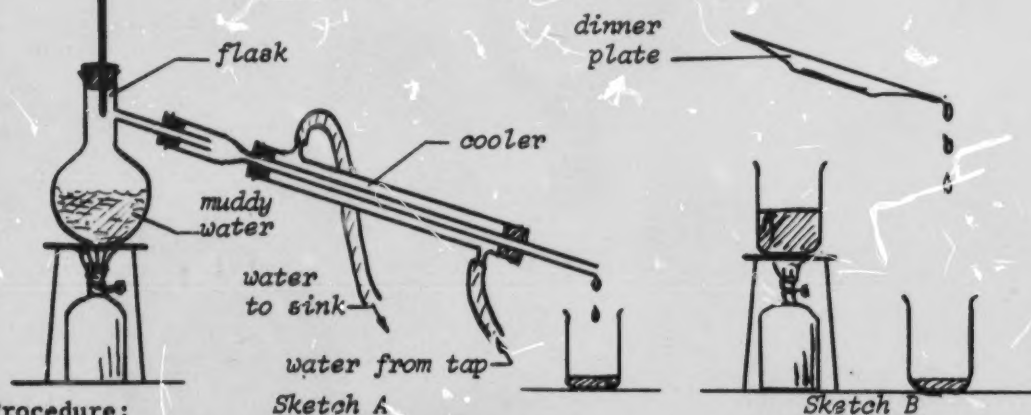
By boiling the water (the purpose of the boiling chips is to obtain an even boiling), steam is formed and this replaces almost all the air above the water in the flask. By closing it off immediately after boiling point is reached with the stopper and the thermometer, the air is trapped out of the flask. When the flask is cooled off with the cold water, the water vapor above the water condenses on the colder surface and a partial vacuum above the water is created. This makes the water boil at much lower temperatures than the normal boiling point of 100° C. Normal indicates the boiling point at normal pressure, which is 760 mm mercury or the barometric pressure at sea level.

CHARACTERISTICS OF MATTER

DISTILLATION BOILING POINT

4.14. DRINK MUDDY WATER

- Materials:**
1. Distillation apparatus (flask, thermometer, cooler) (if not available revert to point 2).
 2. Two beakers (200 ml), and a dinner plate.
 3. Burner (propane) and stand.



Procedure:

1. Set the distillation apparatus up as in Sketch A. Place some muddy water in the flask and start heating it. (If the distillation apparatus is not available, proceed with the following points).
2. Place one beaker on the stand and burner, and fill it with some muddy water. Start heating this.
3. As soon as it starts to boil, hold a large dinner plate somewhat slanted above the beaker (in the steam) and let the condensed water drip into the other beaker (see Sketch B).

Questions:

1. At what temperature does water boil at normal pressure?
2. What temperature do you think would the boiling muddy water have?
3. Why do the impurities stay back in the flask (or 1st beaker)?
4. What is the purpose of the cooler (or dinner plate)?
5. What would be another way to purify the muddy water?
6. Would rain water be the same as distilled water?

Explanation:

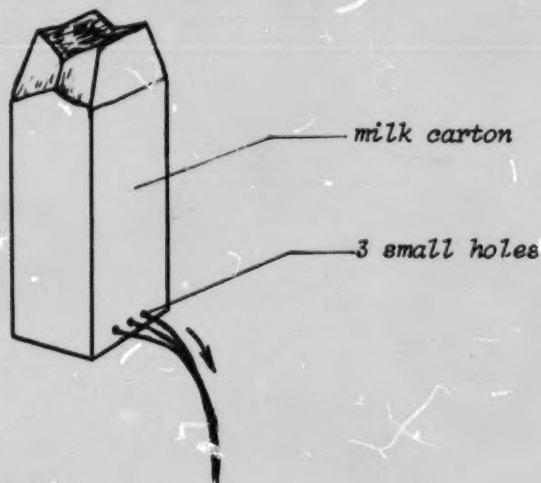
The muddy water in the flask or first beaker would most likely reach a temperature above 100°C before it starts to boil, because of the impurities in the water. The thermometer, however, would indicate the boiling temperature of pure water, which would be a little below or close to 100°C Celsius, depending on the elevation of the place. The impurities stay back in the flask, because it is only the water molecules that jump out of the liquid state into the vapor state, which are condensed back into the liquid state by the cooler or the cool plate. Another way of purifying water for drinking would be to filter it through a thick layer of sand, although it would contain minerals, which distilled water would not. Rain water would pick up dust and chemicals in the air (especially in polluted areas).

CHARACTERISTICS OF MATTER

COHESION

4.15. THE CLINGING WATER STREAMS

Materials: 1. An empty milk carton or tin can.



Procedure:

1. Make three small holes in one of the sides near the bottom of the milk carton—about $\frac{1}{2}$ cm away from each other.
2. Fill the carton full with water and observe the water streams coming out of the holes.
3. Bring the streams together with the fingers to make it one big stream. Separate the streams by pushing one finger through the middle of the large stream (usually it requires several tries to separate them).

Questions:

1. Why does the water stay in one stream once they are brought together?
2. How far can the holes be placed apart for the water still to be able to cling together?
3. Is it easier to separate (or bring together) the streams with a full or almost empty carton?

Explanation:

The closer the holes are placed in the carton, the easier to get a whole stream out of the carton, but the harder to separate it into three separate streams. The farther the holes are, the harder to bring the separate streams together. It is the *cohesive forces* between the water molecules that keep the streams together. The fuller the carton, the larger the pressure, and the easier the separate streams are obtained. With less water in the carton, we will get lower water pressure and thus an easier cohesive whole stream.

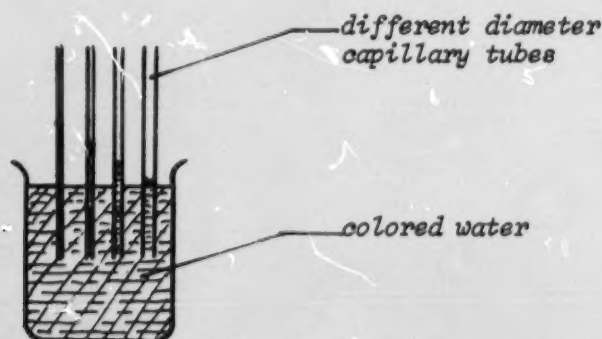
We find this phenomenon in daily life in the shower head with the many holes in it. When the valve is turned wide open, separate streams are distinguished, but when the valve is only partially opened, the many small streams will cling together and form one whole stream.

CHARACTERISTICS OF MATTER

ADHESION

4.16. THE SMALLER, THE STRONGER

- Materials:
1. Three or four capillary tubes of different diameter.
 2. A small beaker & food coloring.



Procedure:

1. Fill the beaker with water and place a few drops of food coloring in it.
2. Hold the three or four capillaries close to each other and dip them in the water: observe the water level in each of the capillaries.
3. When a flat cell is available, the capillaries can be projected on the screen by slanting the overhead projector slightly.

Questions:

1. Will the water level in the capillaries change when the tubes are either moved higher or lower in the beaker?
2. What makes the water go up in the tubes in the first place?
3. Why does the water move up higher in the narrower capillary?
4. Where do we find an application of this capillary action in daily life?
5. What is the force between unlike or like molecules of matter called?

Explanation:

When a capillary tube is dipped in water, the adhesive forces between the water and the glass of the tube are so large that the water is pulled upwards. The smaller the capillary, the more glass surface per unit number of water molecules exists, and thus the larger the adhesive force. Furthermore, the distance between the water molecules and the glass molecules is so much shorter in the narrower tube, that the adhesive attraction between these unlike molecules is greatly increased.

This is how the fibers in plants and trees bring up the water from deep in the ground to high up in the leaves. Capillary action combined with osmotic pressure caused by the semi-permeable walls of the fibers and the plant juices, push up the water to the tree top. Another example of adhesion is the application of paint on any surface. The paint clings to the surface because of the adhesive forces between the paint and the surface molecules.

CHARACTERISTICS OF MATTER

COHESION & ADHESION

4.17. POUR WATER ALONG A STRING

- Materials:**
1. Two beakers or plastic cups.
 2. A water-absorbent string (thin rope).



Procedure:

1. Fill one of the beakers about $\frac{3}{4}$ full with water.
2. Stand a book about 20 cm away from the empty beaker.
3. Show students the string and ask: "How can I transfer the water from beaker A to B without moving beaker A over or around the book?"
4. Wet the string thoroughly in the water.
5. Hold one end of the string in beaker A and the other end over beaker B (see Sketch) and pour the water slowly along the string.

Questions:

1. Why was it necessary for the string to be wet?
2. What forces were holding the water to the string?
3. What other materials can be used in place of the string?
4. Is it possible to pour other liquids along a string?

Explanation:

The string needs to be wetted so that water molecules would adhere to the molecules of the string. The water molecules are attracted to the string molecules by *adhesion*. Once the string is wet, the water can cling to the already present water molecules, because of the *cohesive* forces between like molecules of water. The transfer of water will not succeed with a dry string or any material which is not water absorbent.

Other materials that would have the same properties as the water-absorbent string would do the same job, like: cotton, cloth, paper, wood, etc. Materials that are not water-absorbent, like nylon or wool cannot be used for this purpose.

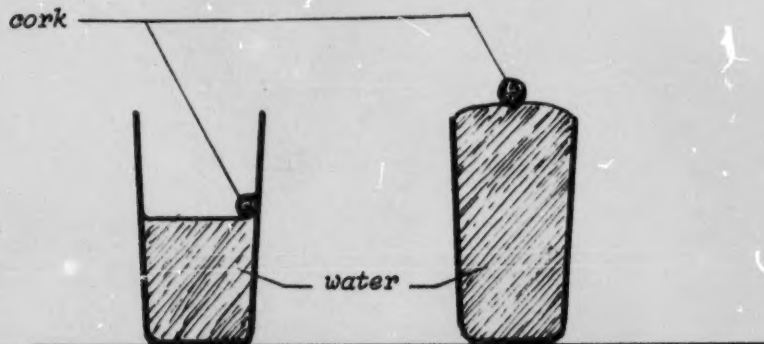
Liquids that have strong cohesive forces between their molecules, like oil, vinegar, sirup, etc. can be poured along a string as well, provided that we make sure that the string or whatever material is used to transfer the liquid can absorb it.

CHARACTERISTICS OF MATTER

COHESION & ADHESION

4.18. WHERE DOES THE CORK FLOAT?

Materials: 1. A regular drinking glass.
2. A small cork.



Procedure:

1. Fill the glass half way with water and float the cork on the water surface: observe!
2. Where does the cork float? (it should be attracted toward the side of the glass; move it somewhat if it stays in the middle).
3. Now add more water to the glass and fill it brimfull. Observe where the cork now floats.
4. Try to push the cork towards the edge: it will not stay there!

Questions:

1. Why is the cork moving towards and sticking to the side of the glass (with the glass half-filled)?
2. Where is the water level highest in the half-filled glass?
3. Why is the cork floating in the center of the full glass?
4. Where is the water level highest in the full glass?
5. Why can we fill the glass more than full without overflowing the water?

Explanation:

When the glass is half-filled with water, the circumference of the meniscus is the highest level. This is caused by the adhesive forces between the water and the glass molecules. As a result of this high level at the side of the glass, the cork moves to that place.

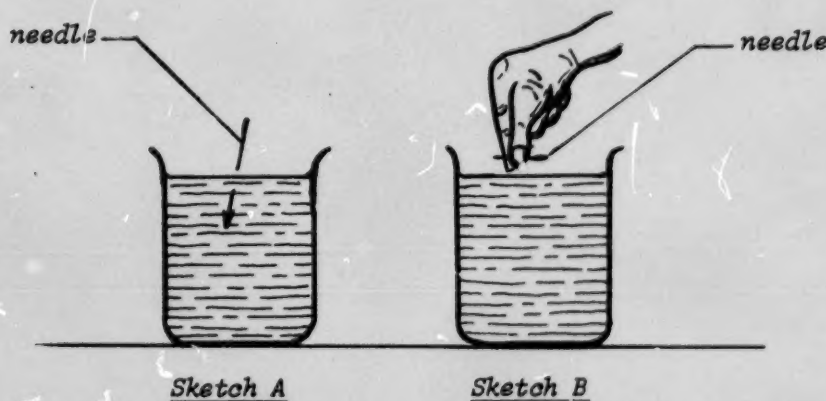
When the glass is brimfull filled with water, the surface tension and the cohesive forces between the water molecules form a film on the surface of the water, making it possible to fill the glass more than full. The highest level of the meniscus is now in the center of the glass, which is where the cork will float. As floating objects tend to float at the highest spots of the meniscus, the center would be the spot where the cork would float when the glass is full.

CHARACTERISTICS OF MATTER

SURFACE TENSION

4.19. FLOAT METAL ON WATER

- Materials:
1. A needle, razor blade, or thin wire gauze.
 2. A beaker, and a candle.



Procedure:

1. Fill the beaker with water.
2. Take the needle or razor blade and show that the density of the metal is higher than that of water by dropping the object vertically in the water (see Sketch A).
3. Fish the needle out of the water and dry it off, or use another needle.
4. Now hold the needle horizontally as close as possible to the surface of the water (without touching the water) and drop it (Sketch B).
5. If this does not succeed, rub the needle against the candle before dropping it on the surface of the water.

Questions:

1. Why is it not possible to float the needle on the water when it is dropped vertically?
2. Why does the needle have to be dry before floating it?
3. What purpose does the rubbing of the needle against the candle have?
4. What property of the water keeps the needle afloat?
5. How can we make a floating needle sink without touching it?

Explanation

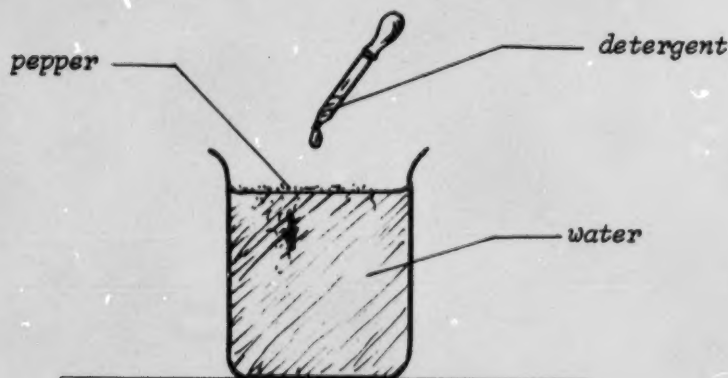
When the needle is dropped vertically in the water, it pierces the water surface. The surface tension at that very small area of the needle point is not large enough to hold the needle afloat. But when the needle is dropped horizontally, parallel with the surface of the water, a much larger area of the water surface is involved, and the combined cohesion forces between the water molecules under and around the needle, which forms the *surface tension*, is large enough to hold the needle afloat. The rubbing against the candle makes the object more water repellant and increases the chance the needle will lie afloat on the film of water molecules.

CHARACTERISTICS OF MATTER

SURFACE TENSION

4.20. SINK THE PEPPER

- Materials:**
1. A beaker or transparent container.
 2. Whole and ground pepper.
 3. Liquid detergent & dropper.



Procedure:

1. Fill the beaker with water.
2. Show the students a whole pepper kernel and ask: "Will the pepper sink or float in the water?" Then drop it in the water: it sinks!
3. Now shake some ground pepper on the water surface. Ask: "Why is the same pepper now not sinking?"
4. Place a drop of detergent in the water and observe the fine pepper now sink to the bottom.

Questions:

1. Why did the same pepper in fine state float on the water?
2. Do you think that pepper has a higher or lower density than water?
3. Did we change the density of the pepper by grinding it?
4. What did the detergent do to the water surface?
5. What forces were weakened between the water molecules when the detergent was added?

Explanation:

By showing the sinking of the whole pepper kernel in the water, the students should be able to conclude that the density of pepper is higher than that of water. The grinding of the pepper is not changing the density of it, yet it floats on the water because the pepper particles are light enough to be held up by the surface tension of the water. The water molecules and their cohesive forces on the surface form a film, which can hold up relatively light objects like a needle, razor blade, gauze, etc.

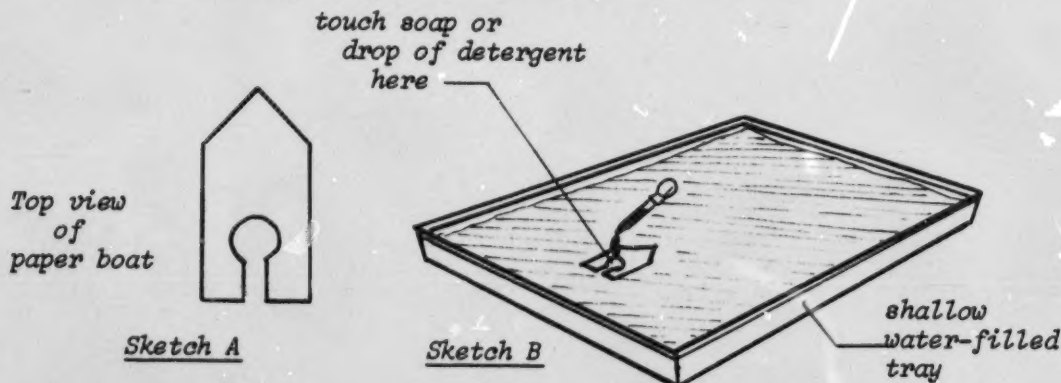
Detergent has the property of breaking the cohesive attraction forces between the water molecules, and thus weakening the surface tension of water. The film on the surface is removed, and the pepper sinks.

CHARACTERISTICS OF MATTER

SURFACE TENSION

4.21. THE DETERGENT PROPELLED BOAT

- Materials:
1. A paper card (3x5"), a shallow tray or sink.
 2. A piece of soap or a few drops of liquid detergent.



Procedure:

1. Fill the shallow tray (or sink) with water.
2. Cut out a boat from the paper card in the form of Sketch A.
3. Let the paper boat float on the water and touch a corner of the soap block to the water in the center opening of the boat (or place a drop of liquid detergent here).
4. Observe the movement of the boat!

Questions

1. Why does the paper boat move forward only when the soap touches the water?
2. What made the paper boat be pulled forward?
3. What did the soap or detergent do to the cohesive forces between the water molecules?
4. What other shapes of boats would work the same way?
5. Would it work without a hole in the paper card?
6. What would happen if we touched the soap to the side of the boat?

Explanation:

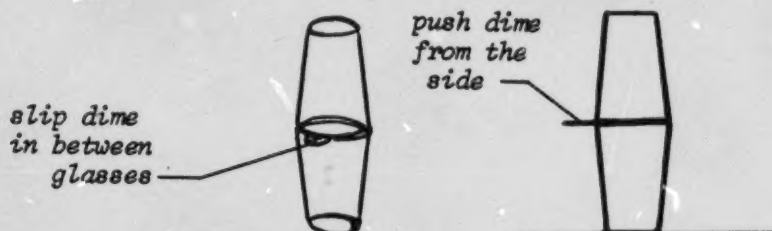
The soap touching the water or the drop of detergent in the water is breaking the *surface tension*. There are *cohesive forces* between the water molecules in front and in the back of the boat, as well as on both sides. By touching the soap towards the rear of the boat, these cohesive forces are broken in the rear but not in the front of the boat. This makes the boat to be pulled towards the front. Similarly, before the detergent was dropped, the water molecules on the surface of the water were pulling the boat on all sides with an equal force. After the detergent was dropped, the attracting force in the rear of the boat was eliminated, so that the resultant force is to the front. The shape of the boat is irrelevant. Any shape will do the same thing. When the surface tension on the left is broken, the paper shape will move to the right. The propelling can continue until the detergent has lowered the surface tension considerably.

CHARACTERISTICS OF MATTER

SURFACE TENSION

4.22. THE WATER-FILLED CUPS

- Materials:
1. Two regular identical drink glasses.
 2. A paper card and a dime (or razor blade).



Procedure:

1. Fill the two glasses with water up to the brim.
2. Place a paper card on one of them and turn the glass upside down while holding the card against the glass.
3. Let go of the card, place the inverted glass on the other water-filled glass, and slip out the card carefully (keeping the top glass exactly over the bottom glass).
4. Place a paper towel around the bottom glass to guard eventual spillage.
5. Ask students: "Can anything be added to the water inside the cups?" (anticipated answer: 'No, not a thing').
6. Take the dime (or razor blade), push the rim in between the two glasses and slip it inside the glasses while holding the top glass.

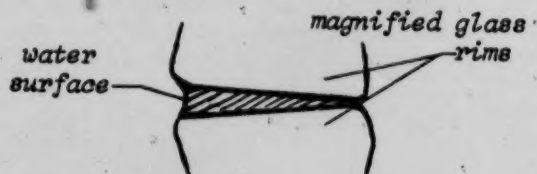
Questions:

1. Why did the water not run out while the dime was slipped in?
2. Did any water spill while the coin was pushed in?
3. What indicated that some water must have run out?
4. What other objects could have been slipped inside the glasses?

Explanation:

In placing the top glass upside down on the bottom water-filled glass, it was the air pressure that held up the card and the water. While the dime (or razor blade) is pushed between the two glasses, some water is running out, which can be detected from the small air bubbles that float up in the top glass. The water in the top glass is held back mostly by air pressure pushing on the water surface between the two glasses. It is as if a film is covering the *surface of the water* - *surface tension*.

Other objects that are as thin as a dime or even thinner could be slipped inside the glasses.

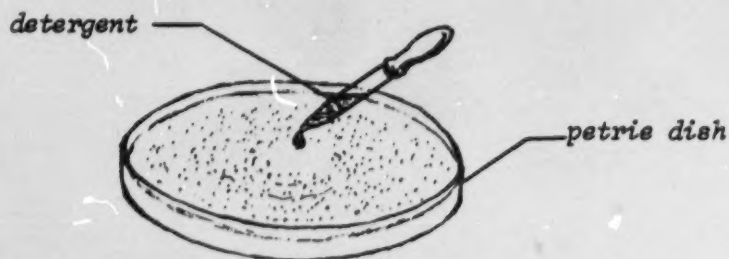


CHARACTERISTICS OF MATTER

SURFACE TENSION

4.23. THE DETERGENT-FEARING POWDER

- Materials:**
1. A Petrie dish (bottom or top), a medicine dropper.
 2. Liquid detergent or soap (solid or powder).
 3. Lycopodium powder (or baking flour or fine pepper).



Procedure:

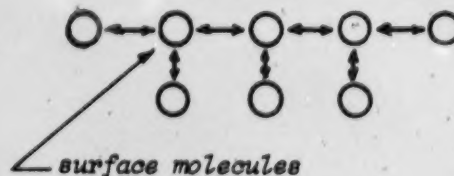
1. Fill a Petrie dish about half full with water (place it on an overhead projector and project the dish on a screen).
2. Sprinkle fine powder (face powder, baking flour, or fine pepper will do) on the water surface.
3. If you have liquid detergent: place a drop in the center of the Petrie dish. Observe the spreading of the powder.
4. If you use solid soap: touch the water surface with a corner of the soap block. Observe!
5. If you have powder soap: drop one or two flakes on the water surface. Observe!

Questions:

1. What made the powder move away from the detergent or soap?
2. What is the detergent doing to the surface tension of the water?
3. What forces are acting on the powder particles on the water surface?
4. What forces are acting between the water molecules on the water surface?

Explanation:

At the surface of the water, the molecules form a film-like layer, where *cohesive forces* are most prominent. The surface molecules have only three sides, where cohesive forces act upon them, as no water molecules are above them. When these cohesive attraction forces are weakened by the detergent at a particular spot, the molecules that are farther away from this spot will pull these weaker held molecules towards them. As the water molecules move, they bring the powder particles with them.

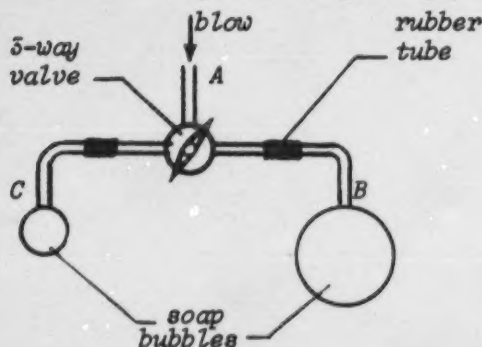


CHARACTERISTICS OF MATTER

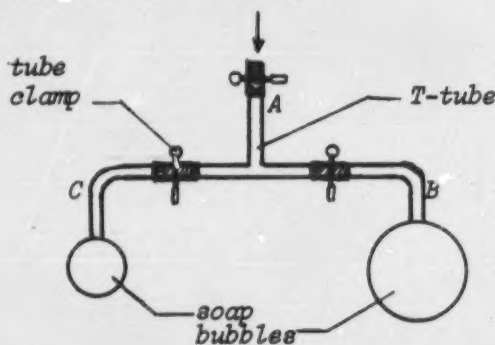
SURFACE TENSION

4.24. WHICH BUBBLE IS STRONGER?

- Materials:**
1. A three-way glass valve or a T-tube with 3 rubber tube clamps.
 2. Two (or three) short rubber tubes.
 3. Two L-shaped glass tubes.
 4. Liquid detergent, glycerine, a small beaker.



Sketch 1



Sketch 2

Procedure:

1. Clamp the three-way glass valve and connect the L-tubes to the short rubber tubes as in Sketch 1.
2. When no valve is available: use a T-tube with 3 rubber tubes and 3 tube clamps, and set the materials up as in Sketch 2.
3. Mix in a small beaker: 1 volume detergent, $2\frac{1}{2}$ volume glycerine and 3 volumes of water.
4. Dip the end of the L-tubes in the detergent mixture by bringing the beaker with the mixture to the set-up.
5. Set the valve such that tubes A & B are connected (when using a valve), or press open clamp A & B, and blow a large bubble on arm B by blowing through tube A.
6. Turn the valve such that tubes A & C are connected (when using a valve), or press open clamp A & C (close clamp B) and blow a small bubble on C.
7. Now freeze the air flow and ask: "Which one will blow which bubble up if they are connected to each other?"
8. Connect the two bubbles by turning the valve (when using a valve) or by pressing (opening) clamps B & C, (close clamp A) and observe.

Questions:

1. Which one is blowing which bubble up?
2. What can we conclude about the relationship between surface tension and radius of a soap bubble?

Explanation:

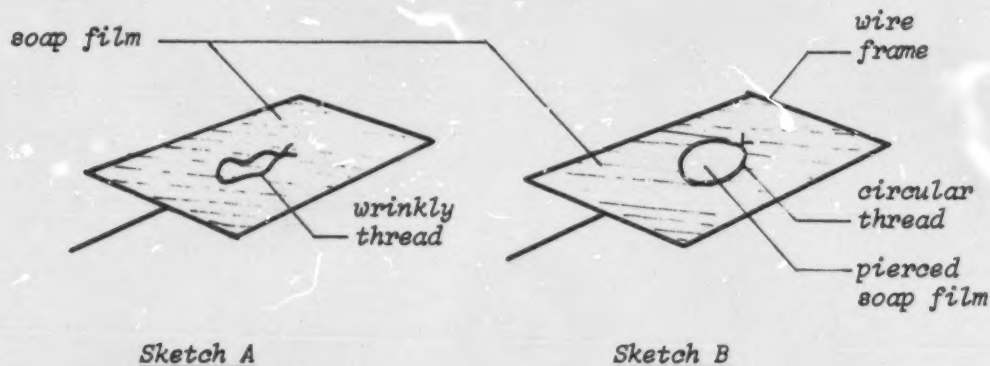
The smaller bubble will blow up the larger one, once the two bubbles are connected. This is because the surface tension in a soap bubble is inversely proportional to the radius of the bubble: the larger the bubble, the smaller the surface tension, thus the lower the pressure inside it.

CHARACTERISTICS OF MATTER

SURFACE TENSION

4.25. THE THREAD CIRCLE IN THE SOAP FILM

- Materials:
1. A liquid detergent (preferably JOY), & glycerin.
 2. A square or rectangle wire frame and thread.
 3. A wide shallow container/tray (to fit the wire frame).



Procedure:

1. Make a soap solution by mixing the following liquids: 1 part JOY, $2\frac{1}{2}$ parts glycerin, and 3 parts water.
2. Place this soap solution in the shallow container, make a soap film by dipping the wire frame in the solution and taking it slowly out.
3. Make a small loop of thread (diam. 3-4 cm), wet it in the soap solution and lay it carefully in the soap film (see Sketch A).
4. Once the thread loop lies in the soap film, pierce the center of the loop with a dry object (pencil or dry finger).
5. Slant the wire frame, wiggle it, and observe the perfect thread circle move and travel throughout the whole frame!

Questions:

1. What made the wrinkly thread turn into a perfect circle?
2. What does the circular loop indicate about the forces working on it?
3. The thread circle stays the same shape no matter where it is in the wire frame, what does this indicate about the forces working on it in the soap film?

Explanation:

This demonstration shows that there is indeed a tension working in the soap film. The wrinkly thread loop lying in the soap film suddenly turns into a perfect circle, after the inside of the loop is pierced, because the forces inside the loop are eliminated, and equal forces at all points on the outside of the loop are working and pulling on it.

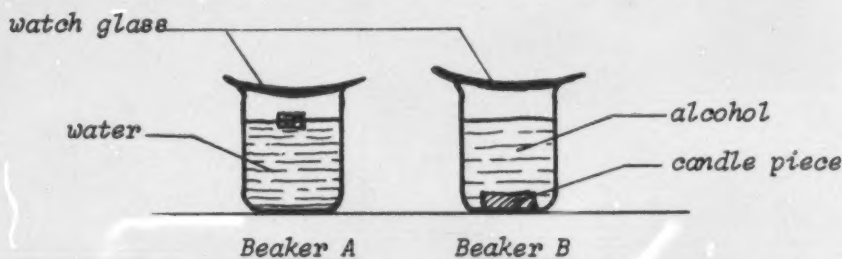
By tilting and wiggling the wire frame, the thread loop can move around the frame without changing shape, as a result of the cohesion forces in the soap film that are of equal magnitude throughout the whole film.

CHARACTERISTICS OF MATTER

DENSITY

4.26. THE FUNNY WATER

- Materials:
1. Two identical beakers, two identical watch glasses.
 2. One small and one larger piece of candle.
 3. Alcohol (methyl, ethyl, or isopropyl).



Procedure:

1. Fill beaker A about 3/4 full with water and beaker B with the same amount of alcohol and cover them with the watch glasses (do not reveal to students that the liquids are different).
2. Show the students the two pieces of candle: drop the short piece in beaker A and the longer candle in beaker B.
3. Ask: "Why is one candle floating and the other sinking?"
"What will the candles do if I switch them around?"
4. Drop the long candle in beaker A (it still floats) and the short one in beaker B (it sinks).

Questions:

1. Why does the candle float in beaker A?
2. Why does the candle sink in beaker B?
3. What does it depend on whether something floats or sinks in water?
In oil? In alcohol?
4. How is density of a substance defined?

Explanation:

The alcohol has a lower density than water. This is why the candle sank in the alcohol and stayed afloat in water. Some students may suggest that it sank in beaker B because it is longer than the other piece that stayed afloat. But then, after switching the pieces of candle around, the longer candle stays afloat in the water and the shorter one sinks in beaker B. This most likely will give students a clue, that the liquid in beaker B is some kind of "funny water". This liquid may be methyl, ethyl or isopropyl alcohol, which all have a density of around .76. The density of water is 1, and that of wax in the vicinity of .85.

Density is defined as the ratio of mass and volume of a substance.

$$D = \frac{M}{V} \quad \text{in which } D = \text{Density, } M = \text{Mass, and } V = \text{Volume.}$$

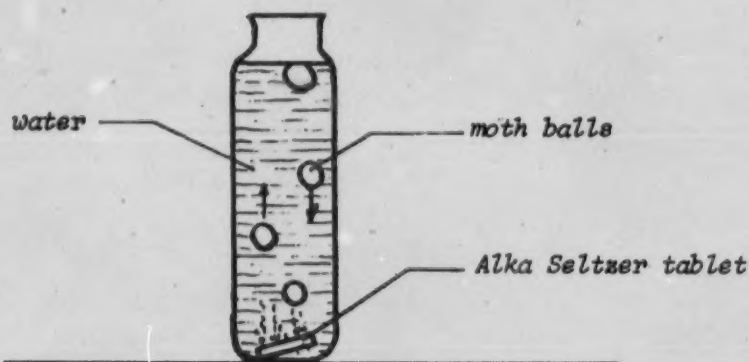
Whether something sinks or floats depends on the relative density of the object compared to that of the liquid it is immersed in. Any object that has a density between that of water (1) and that of alcohol (.76) may be used for this demonstration.

CHARACTERISTICS OF MATTER

DENSITY

4.27. THE BOBBING MOTHBALLS

- Materials:
1. A graduated cylinder or narrow tall jar.
 2. Four or five mothballs
 3. One or two Alka Seltzer tablets.



Procedure:

1. Fill the cylinder or jar with water.
2. Drop an Alka Seltzer tablet (or any other tablet that produces carbon dioxide gas) in the water, and immediately afterwards the mothballs.
3. Let students observe the mothballs (bobbing up and down).

Questions:

1. Why do the mothballs sink in the beginning (when they were dropped)?
2. What makes some mothballs bob up?
3. Why do the mothballs float only for a short while at the surface of the water?
4. What is the purpose of the Alka Seltzer tablet?
5. Would the mothballs bob up and down without the Alka Seltzer?
6. What do you observe the difference is between the rising and sinking mothballs? (observe closely!)
7. What other liquid would give off carbon dioxide bubbles by itself?

Explanation:

The mothballs have a density of a little over 1, so that they just sink in water. When the gas bubbles from the Alka Seltzer tablet adhere to their surfaces, they get lighter and rise up. As soon as they reach the surface of the water, the bubbles burst. This makes the mothball become heavier again causing it to sink.

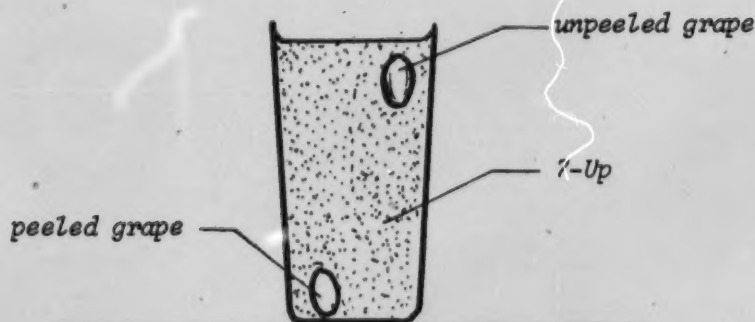
If Alka Seltzer tablets are not available, other tablets that fizz in water may be used. Soda pop drinks, like 7-Up could also be replacing it. These have the gas already dissolved in them and when they are poured in the jar, the bubbles escape, giving the same effect as the Alka Seltzer tablets' bubbles.

CHARACTERISTICS OF MATTER

DENSITY

4.28. WHICH GRAPE IS HEAVIER?

- Materials:
1. Fresh grapes & 7-Up soda pop.
 2. A clear drinking glass.



Procedure:

1. Pour and fill the glass with 7-Up soda pop.
2. Peel one grape (take the skin off and leave the grape whole).
3. Take another unpeeled grape in the other hand and pose the students the question: "Which of the two grapes is heavier?" (anticipated answer: 'the unpeeled one'--which is true!).
4. Drop both grapes (a peeled and unpeeled one) in the 7-Up and observe what they do.

Questions:

1. Why does the peeled grape sink to the bottom?
2. Which of the two grapes is lighter in weight?
3. What makes the unpeeled grape float?
4. Would an unpeeled grape also float in water?
5. Could we do this same demonstration with water and Alka Seltzer?
6. What property does the grape peel have?

Explanation:

This demonstration is also very suitable in the teaching of adhesive and cohesive forces (bubbles adhering to the grape skin). The unpeeled grape has water repelling--*hydrophobe*--properties and thus the CO_2 bubbles from the 7-Up can adhere to this surface.

The peeled grape lacks this *hydrophobe* skin (it is *hydrophil*: water-attracting) and the bubbles of the 7-Up have no way of adhering to the grape. This causes the grape to stay at the bottom of the glass. The unpeeled grape becomes lighter in weight, because of the adhering bubbles, and rises to the surface of the liquid. There it loses some of the bubbles to become heavier again. It may sink a while, picking up more bubbles, to bob up to the surface again.

CHARACTERISTICS OF MATTER

DENSITY

4.29. THE DIFFERENT CLAY STICKS

- Materials:**
1. Molding clay and a short wooden stick.
 2. A technical balance or equal arm balance.
 3. Two beakers (glass or clear plastic).



Procedure:

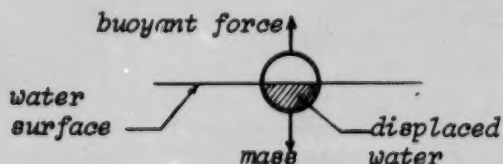
1. Wrap just enough clay around a short wooden stick, so that it would just barely float in water.
2. Place this on one pan of the equal arm balance and weigh off the same mass of clay on the other pan.
3. Roll a cylinder out of this mass of clay. You are now ready for the inquiry demonstration.
4. Show the students the two beakers filled with water and the two clay cylinders (to be placed in the water).
5. Show them that they weigh exactly the same, by placing them on each pan of the equal arm balance.
6. Now drop them in the two beakers with water (one sinks and one floats!).

Questions:

1. Why does one clay cylinder sink and why does the other float?
2. What property is the same for both sticks?
3. What property does it depend on whether an object sinks or floats in a certain liquid?
4. What force is holding the floating object afloat?

Explanation:

Although the mass of the two clay sticks are equal, the volume is definitely not the same, because the much lighter wooden stick is inside the one that floats. Since the density may be calculated from $D = M/V$, it can be seen that the density of the floating cylinder is smaller than the one that sinks. The force that holds up the floating cylinder is the buoyant force, which is the mass of the displaced liquid (water in this case). If the mass of the displaced water is the same as the mass of the object, it will float. If the former is less than the mass, the object sinks.



CHARACTERISTICS OF MATTER

DENSITY

4.30. IS THE CROWN MADE OF PURE CLAY?

- Materials:**
1. Molding clay, some sawdust or wood chips.
 2. A graduated cylinder or graduated beaker.
 3. An equal arm balance or technical balance.



Procedure:

1. Make "impure" clay by mixing some sawdust or wood chips in the clay.
2. Now make an intricate shape (like a crown) out of the "impure" clay, and ask: "How can I find out whether the crown is made of pure clay or not?" (or tell the story of the King and Archimedes).
3. Weigh pure clay on the balance of the same mass as that of the crown.
4. Determine the volume of the crown and the pure clay by immersing them one by one in the graduated beaker. (Read off the water level before and after immersion and calculate the difference).

Questions:

1. If the crown and the clay ball were to displace the same amount of water, what may we conclude about the crown?
2. If the crown is made of impure clay, how would the two volumes differ?
3. Why does the ball need to be of the same mass as the crown?
4. What property are we actually determining of the crown?
5. What property is determined by immersing the object in water?
6. How did Archimedes determine the density of the King's crown?
7. Is density a specific characteristic of a substance?

Explanation:

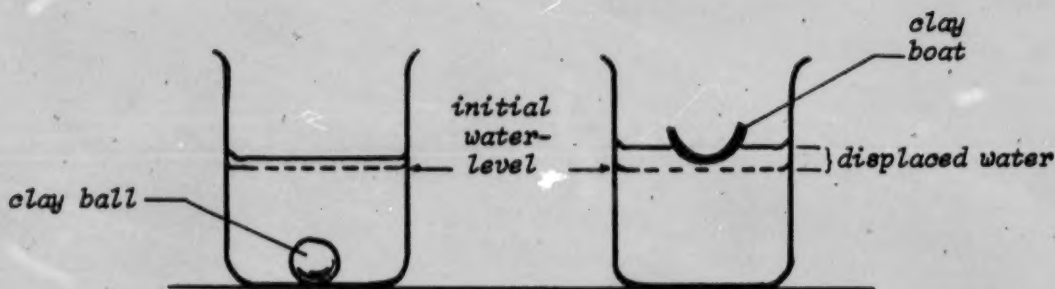
The King suspected that his crown maker had cheated on him (by mixing in copper with the gold), so he summoned Archimedes to check whether his crown was made of pure gold or not. Archimedes made use of the definition of density ($D = M/V$); so he weighed in pure gold, the same mass as that of the crown, and then determined the volume of the crown and the chunk of gold by immersing it in water. If the crown were made of pure gold, the density of both objects should be the same, thus also the volume of the displaced water. If the volume of the crown came to be larger than that of the gold chunk, it would have been made of impure gold.

CHARACTERISTICS OF MATTER

DENSITY

4.31. CAN YOU MAKE CLAY FLOAT?

- Materials:
1. A lump of molding clay.
 2. A large beaker or transparent container.



Procedure:

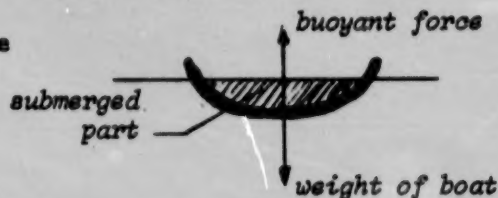
1. Make a ball of clay with a diameter of about 5 cm.
2. Fill the beaker half way with water and mark off the water level.
3. Ask students: "Will clay float or sink in water?" Plunge the clay ball in the water, mark off the water level, and take it back out.
4. Transform the same ball of clay into a small boat (make sure it is watertight), and let it float on the water.
5. Draw students' attention to the water level with the floating clay boat on the water.

Questions:

1. Was the clay ball heavier than the clay boat?
2. Which of the two displaced more water?
3. What is the volume of the displaced water equal to?
4. What is the weight of the displaced water equal to?
5. Would we be able to float iron or lead this same way?

Explanation:

The clay ball and clay boat were of the same weight, because the boat was made of the one and the same clay ball, and as mass is conserved and no clay has been taken away or added, the mass and thus the weight is the same. The boat, however, displaced more water because of its shape. The volume of this displaced water is equal to the volume of the submerged part of the boat or ball, whereas the weight of the displaced water is equal to the buoyant force, which is the force upward. This is equal to the mass of the clay boat when floating, but less than the mass of the clay ball (this is why the ball sinks).

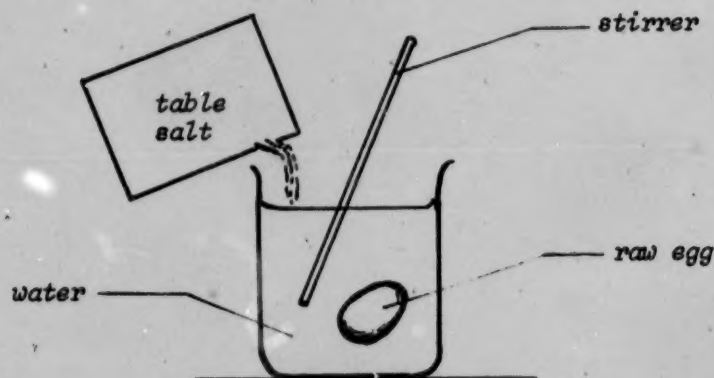


CHARACTERISTICS OF MATTER

DENSITY

4.32. FLOAT THE EGG WITH SALT

- Materials:
1. A raw chicken egg & table salt.
 2. A large beaker or plastic container & stirrer.



Procedure:

1. Fill the beaker about 2/3 full with water.
2. Ask students: "What will the egg do in the water, sink or float?" Immerse the egg carefully in the water.
3. Add salt to the water while stirring carefully (remember it is a raw egg), until the egg starts to float.
4. Try to dissolve other chemicals (instead of salt) in the water, like sugar, baking soda, corn syrup, etc.

Questions:

1. What would the density of the raw egg be compared to pure water?
2. By adding the salt to the water, what property was increased?
3. What two entities are we comparing, when we want to know whether an object will float in a particular liquid or not?
4. Would the egg float in alcohol? In corn syrup? In oil?
5. How can we determine the volume of an egg?
6. How can we calculate the density of an egg?

Explanation:

From the behavior of the egg in water, it can be seen that the density of the raw egg is a little larger than that of pure water. It can actually be determined by weighing the egg and finding the volume of it by measuring the displaced water (the difference between the water levels), and by dividing this volume into the mass (weight) of the egg.

By adding the salt to the water, the density of the water is increased. The mass of the displaced water is therefore also increased, and as this mass equals the buoyant force, the egg gets a larger force acting upwards upon it, and thus at a certain moment floats up. At this moment, the buoyant force is equal to the egg's mass. For this same reason it is much easier to swim in sea water compared to fresh water.

CHAPTER 5

HOW DO CHEMICALS BEHAVE IN OUR DAILY LIFE ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts of this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

- The existence of physical versus chemical changes.
- The different colors of indicators in acids and in bases.
- Reactions that produce gas.
- The solubility of chemicals in water.
- Reactions that produce precipitates.
- Replacement and catalytic reactions.
- Exothermic and spontaneous combustion reactions.

CHEMISTRY

PHYSICAL &
CHEMICAL CHANGE5.1. THE CHARCOAL SAUSAGE

- Materials:
1. About 100 ml of sugar crystals.
 2. Two 100 ml beakers, two glass stirrers.
 3. Concentrated sulfuric acid (H_2SO_4).

Procedure:

1. Fill each beaker half full with sugar.
2. Add about 40 ml of water to the first beaker and the same amount of concentrated sulfuric acid to the second beaker; stir and let stand.
3. Observe the difference between the two changes in the sugar.
Ask: "In which beaker do the reactants still have the same properties?"
(the reaction should preferably be carried out under a fume hood or close to an open window, or in the outdoors).

Questions:

1. What is the difference between the processes in beaker I and II?
2. How can we recognize or distinguish between a physical change and a chemical change?
3. In which of the two beakers could we get the sugar back as sugar?
4. What do you think happened in the second beaker?
5. What property do you think concentrated sulfuric acid has?
6. What do you think the black material in beaker two is?

Explanation:

In beaker I, where the sugar was mixed with the water, a physical change was taking place. This means that the components of the mixture retained their properties; they could be separated and still have the exact properties as before the change. The water could be left to evaporate and the sugar would crystallize out of the solution.

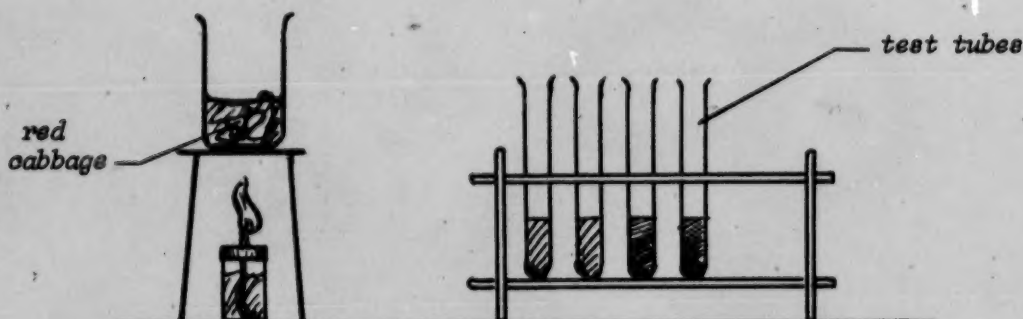
In beaker II a chemical change took place, leaving products, which have properties that are completely different from the original components of the mixture. A black charcoal mass is produced, which is expanding up because of the gases (SO_2) and water vapor being released. This is caused by the dehydrating properties of concentrated sulfuric acid.

CHEMISTRY

ACIDS & BASES

5.2. THE BLUE & RED CABBAGE

- Materials:
1. A few leaves of red cabbage.
 2. A small beaker and four test tubes (test tube rack).
 3. An alcohol burner and stand.
 4. Vinegar, lemon juice, baking soda, lime.

Procedure:

1. Cut a red cabbage leaf in small pieces; place it in the beaker and add about 10 ml of water to it.
2. Heat it above the burner until boiling, then pour equal amounts of the liquid in the four test tubes.
3. Place a few drops of vinegar in the first and a few drops of lemon juice in the second test tube: have students observe closely the color of the liquid.
4. Now add a pinch of baking soda to the third and a pinch of lime to the fourth test tube: observe the color change!

Questions:

1. Which two chemicals colored the cabbage juice red?
2. Which two colored the cabbage juice blue?
3. What would happen if we added baking soda to the cabbage leaf?
4. To which of the two groups of chemicals would orange juice belong? Pineapple juice? Grape juice? Soap water?
5. What would happen if we added vinegar to the blue liquid?

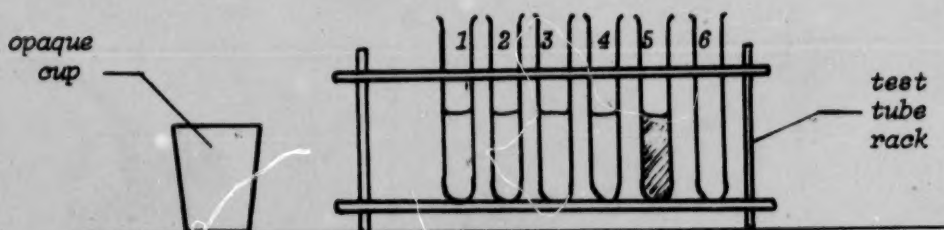
Explanation:

The red cabbage juice acts like litmus, an indicator that turns red in acids and blue in bases. Vinegar, lemon juice, and other sour tasting juices are all acids; whereas baking soda, lime, and soap water are bases. Chemists are talking in terms of pH (which will be dealt with in higher grades: the negative logarithm of the hydrogen ion concentration). A pH of 7 for a neutral liquid, less than 7 for acids, and higher than 7 (up to 12) for bases.

Other common indicators are: litmus paper, phenolphthalein, methyl orange, methyl red, universal indicator.

5.3. THE FUNNY COLORS

- Materials:**
1. A test tube rack with six test tubes.
 2. Dilute hydrochloric acid (HCl).
 3. Dilute sodium hydroxide solution (NaOH).
 4. Phenolphthalein indicator, and a drinking straw.
 5. Medicine dropper, an opaque cup (styrofoam will do).

**Procedure:**

1. Number the six test tubes to avoid confusion.
2. Tape a white paper behind the tube rack for easier distinction of the pink color in the test tubes (a spot light will help).
3. Place 3 drops of phenolphthalein in test tube No. 2 and 4; and 3 drops of NaOH in test tube No. 6 and the cup each; and 3 drops of HCl in test tube No. 5.
4. Fill the opaque cup with drinking water from a pitcher, then halfway fill test tube 1, 2, 3, & 4 from the cup (2 & 4 appear pink).
5. Say: "There must be something wrong!" Pour the four test tube contents back into the cup. Now fill test tubes 1, 2, 3, 4, & 5. (all are pink except for No. 5).
6. Say: "What now?" Pour all 5 tubes back and fill all six tubes. No. 6 stays pink. Blow color away with the straw!

Questions:

1. What made the pink color in test tube No. 2 and 4?
2. What made the color disappear in test tube No. 5?
3. What is in our breath that can neutralize the basic solution?
4. What else could we use to take away that pink color of tube 6?

Explanation:

Phenolphthalein is an indicator for basic solutions. It turns pinkish red in dilute sodium hydroxide solution or any other basic solution (with a pH higher than 7). Test tube 5 contains hydrochloric acid, which will neutralize the base being poured in it. The pH is brought back to lower than 7 and thus turning the liquid colorless.

The air that human beings are exhaling contains more carbon dioxide than atmospheric air. This gas is slightly acid in water and neutralizes the weak basic solution. Other substances that can be used to neutralize bases are: vinegar (acetic acid), lemon juice (citric acid), etc.

CHEMISTRY

GAS PRODUCTION

5.4. GRIND A CRACKER

- Materials:
1. A mortar and pestle, & scoop.
 2. Potassium chlorate (KClO_3), and sulfur (S) powder.

Procedure:

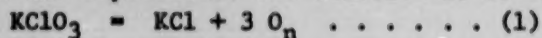
1. Take a tip of a scoop of potassium chlorate and the same amount of sulfur and place it in the mortar.
2. Now show the students as if you were just casually mixing the two powders. Put a little pressure on the pestle (hold the mortar and pestle with outstretched arms), and watch the students jump out of their seats!
3. The more reactants are ground together, the louder the explosion!

Questions:

1. What are the products of the reaction?
2. Why do we hear an explosion in general?
3. What happens to the air in a bursting balloon?
4. What made the explosions in the mortar?
5. What do you think the rate of gas production is in this reaction?

Explanation:

We can hear an explosion, because a sudden large wave in the air hits our ear drums. This large wave is usually caused by a sudden expansion or production of gas. In this case a sudden production of sulfur dioxide (SO_2) is the cause of the explosions. The reaction is as follows:



The grinding of the powder causes heat to develop between the mortar and the pestle, which triggers reaction (1) to proceed to the right. The oxygen released in *status nacendi* (O_n) is in atomic form and very reactive, thus immediately attacking the surrounding sulfur (reaction 2).

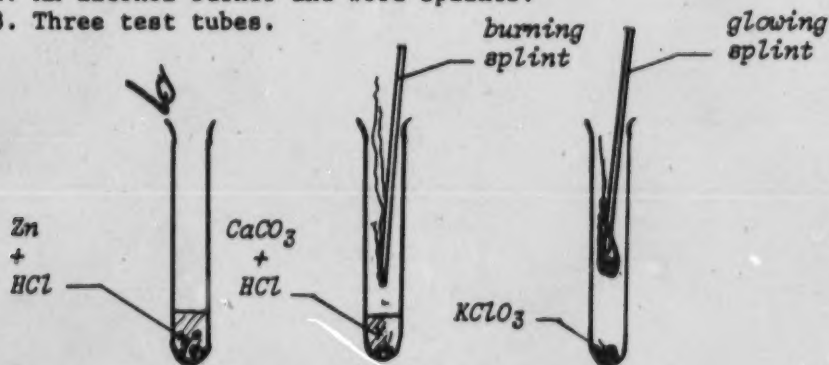
The sudden production of SO_2 gas causes a sudden movement of the surrounding air, thus a large wave is created and this reaches our eardrum, with the result of hearing the explosion. Potassium chlorate is very much used in the firecracker industry, together with charcoal and sulfur.

CHEMISTRY

GAS PRODUCTION

5.5. WHICH GAS IS WHICH?

- Materials:**
1. Zinc powder or chips, calcium carbonate (marble chips), potassium chlorate, and hydrochloric acid (dilute).
 2. An alcohol burner and wood splints.
 3. Three test tubes.

Procedure:

1. Place a few zinc chips in the first test tube, add about 3 ml of dilute HCl, and place your thumb over the tube. Light a match and bring it close to the test tube's mouth: release thumb!
2. In the second test tube, put a few marble chips and add about 3 ml of dilute HCl. Burn a wood splint and lower the flame into the test tube. (What happens to the flame?)
3. Put a little KClO₃ plus a little of the burnt ashes from the wood splint into the third test tube. Mix them by shaking the tube and heat it slowly over the alcohol flame. Test the gas with a glowing wood splint (not a burning one; flame should be blown off before inserting in tube).

Questions:

1. What gas is produced in the first test tube?
2. What unique characteristics does this gas possess?
3. What gas is produced in the second test tube?
4. How can we recognize this second gas from the others?
5. What gas is produced in the third test tube?
6. How different is this third gas compared to the other two?

Explanation:

In test tube I: $\text{Zn} + 2 \text{HCl} = \text{ZnCl}_2 + \text{H}_2$; Zinc chloride and Hydrogen gas is produced. This gas is highly flammable and gives off a characteristic small explosion, when ignited in the test tube.

In test tube II: $\text{CaCO}_3 + 2 \text{HCl} = \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$; calcium chloride, water, and carbon dioxide are formed. This gas is also invisible, but it has the property of extinguishing a flame.

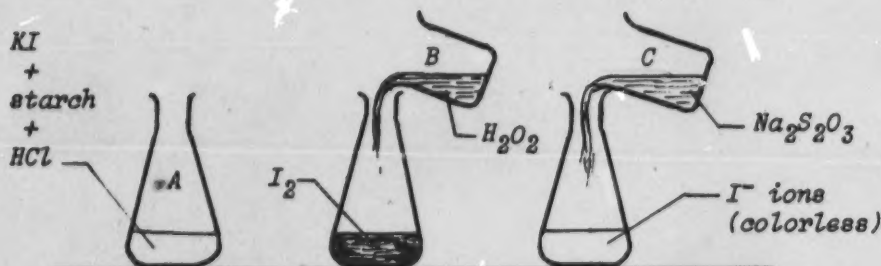
In test tube III: $2 \text{KClO}_3 = 2 \text{KCl} + 3 \text{O}_2$; potassium chlorate is decomposed by heat into potassium chloride and oxygen gas, which makes a glowing splint flare up. Oxygen is present in the air and makes up 20% of the atmospheric air: a necessary component for all living things.

CHEMISTRY

RATE OF REACTION

5.6. THE RETURNING COLOR

- Materials:**
1. One Erlenmeyer flask (medium size), & two beakers.
 2. Potassium iodide (KI), hydrogen peroxide (H_2O_2), sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$), starch solution, and dilute hydrochloric acid (HCl).

**Procedure:**

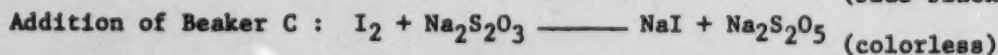
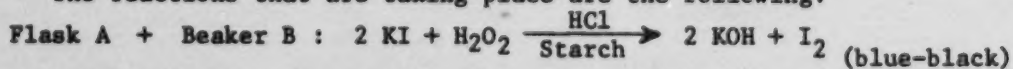
1. Dissolve a little KI in water, add some starch solution and a little dilute HCl (Sketch A).
2. Prepare solutions in beaker B and C. Place a 3% H_2O_2 solution in beaker B; dissolve some $\text{Na}_2\text{S}_2\text{O}_3$ in about 100 ml of water in beaker C.
3. Add to flask A some of liquid B (turns blue-black) and immediately afterwards a little of liquid C (turns colorless).
4. Place flask on table and observe: sudden color change!
5. The addition of liquid C can be repeated several times. (To make it more interesting, after addition of liquid C, hold the flask behind your back for a few moments and bring it back on the table as a blue-black solution).

Questions:

1. How is the blue-black color created?
2. What was it that took away the color?
3. Which reaction is slower? The color-producing or the color-removing one?
4. How long can we keep repeating the second reaction?
5. What reactions are usually slower in rate?

Explanation:

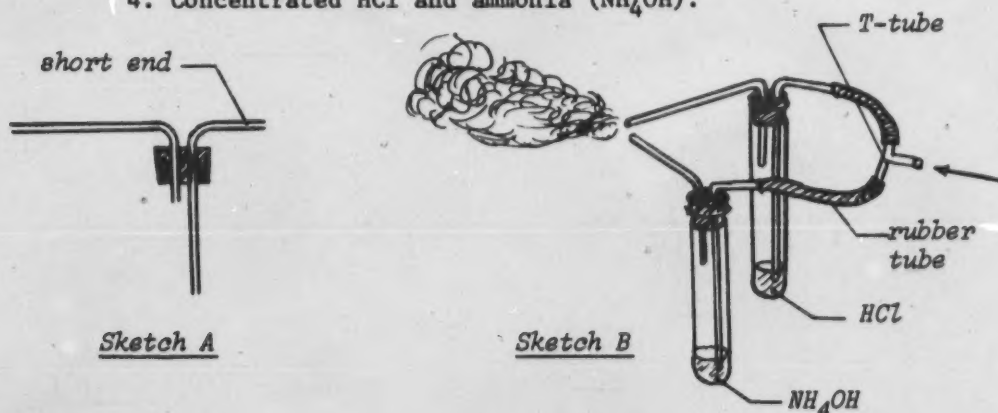
The reactions that are taking place are the following:



Reaction (1) is an oxidizing reaction, where the iodide ions are oxidized into iodine, which turns starch into a blue-black color. The addition of $\text{Na}_2\text{S}_2\text{O}_3$ reduces the iodine back into iodide ions, which are colorless. The fact that the blue-black color keeps on returning, even after the $\text{Na}_2\text{S}_2\text{O}_3$ is added, shows that the first reaction is still proceeding and thus is a much slower reaction than the first.

5.7. MAKE A SMOKE SCREEN

- Materials:**
1. Two wide (large size) test tubes.
 2. Four L-shaped glass tubes in two 2-hole stoppers.
 3. A T-tube and two pieces of rubber tubing.
 4. Concentrated HCl and ammonia (NH_4OH).

**Procedure:**

1. Fit the four L-tubes in the two 2-hole stoppers as in Sketch A.
2. Attach two rubber tubes to the short ends of the L-tubes above the rubber stopper (see Sketch A).
3. Attach the other end of the two rubber tubes to the glass T-tube (see Sketch B).
4. Place about 10 ml of concentrated hydrochloric acid (HCl) in one test tube and 10 ml of concentrated ammonia (NH_4OH) in the other.
5. Close the test tubes off with the stoppers (and tubes in them).
6. Hold the two test tubes in one hand (making sure that the two free ends of the glass tubes are close together), hold the T-tube in the other hand, and blow through the free end of the T-tube.

Questions:

1. What reaction is taking place?
2. What is making up the smoke particles?
3. How could we do this reaction without the glass and rubber tubes?
4. What does smoke in general consist of?

Explanation:

The reaction that takes place where the smoke is formed, is as follows:
 $\text{NH}_4\text{OH} + \text{HCl} = \text{NH}_4\text{Cl} + \text{H}_2\text{O}$. The NH_4Cl (ammonium chloride) is a solid and as the reactants are gases or actually fine mists, the ammonium chloride formation results in very fine solid particles. Smoke is exactly this: a fine suspension of solid particles in a gas. Smoke that is used for sky-writing by planes, is produced by spraying special oils and parafins on the hot exhaust of the airplane.

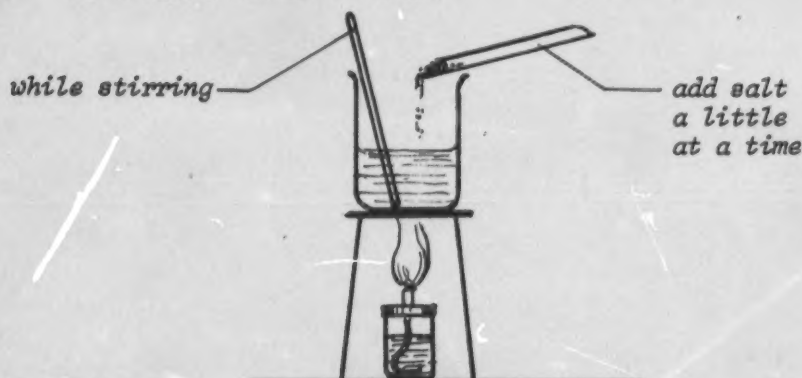
If glass and rubber tubes are not available, the reaction can also be accomplished by holding the mouths of the two test tubes with HCl and NH_4OH close to each other.

CHEMISTRY

SOLUBILITY

5.8. DISSOLVE MORE SALT BY COOLING?

- Materials:**
1. Sodium nitrate, sodium chloride, potassium nitrate, potassium chloride, calcium acetate.
 2. Three beakers (250 ml), stirrers, & scoop.
 3. Alcohol burner & stand.

**Procedure:**

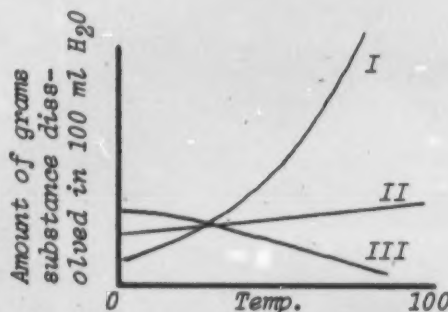
1. Make a saturated solution of each of the following salts: potassium nitrate (or sodium nitrate or potassium chloride), sodium chloride, and calcium acetate, at room temperature, by adding half a teaspoon at a time to 100 ml of water, until some solid is left behind after stirring for one minute. (stir after every addition of solid).
2. Now heat beaker I (with KNO_3) and as soon as the solid particles dissolve, add half teaspoon at a time until some solid stays undissolved.
3. Do the same with beaker II (NaCl): not as much can be dissolved!
4. Heat beaker III (with Ca acetate): more solid precipitates out!

Questions:

1. How could we dissolve more Ca acetate in Beaker III?
2. Most salts behave like the first two salts; what variable goes up with increasing temperature?
3. Which of the salts could dissolve much more with increasing temperatures?
4. What happened to the three salt solutions after being cooled?

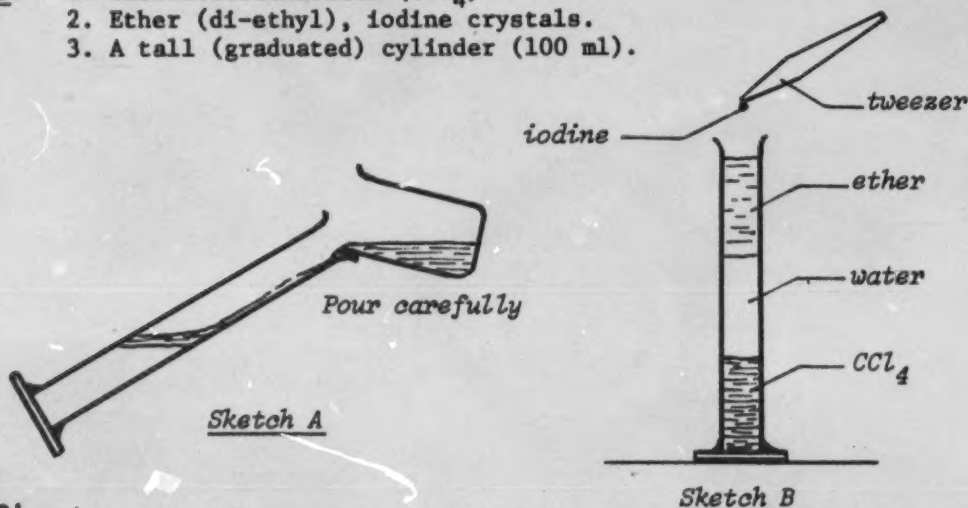
Explanation:

The solubility of a substance is generally increasing with increasing temperatures (see solubility curves I and II on the right). Solubility curve III is very seldom encountered. Students can keep track of the amount of salt added to the water and the temperature, in order to plot a solubility curve.



5.9. THE THREE-LAYERED LIQUID

- Materials:
1. Carbontetrachloride (CCl_4)
 2. Ether (di-ethyl), iodine crystals.
 3. A tall (graduated) cylinder (100 ml).

Procedure:

1. Pour about 30 ml of carbontetrachloride in the cylinder.
2. Carefully pour 30 ml of water on top of the carbontet, by slanting the cylinder when pouring (see Sketch A).
3. Do the same thing with 30 ml of ether on top of the water.
4. Stand the cylinder on the table and drop several crystals of iodine in the layered liquid. Observe the colors.

Questions:

1. Why did the water float on top of the carbontet?
2. Would ether be able to float on top of carbontetrachloride?
3. What does it depend on whether we can make layered liquids or not?
4. Why did we get different colors in the liquid?
5. What does a dark color indicate about the solubility?
6. In what liquid did iodine dissolve the least?
7. With what other liquids could we make layers?

Explanation:

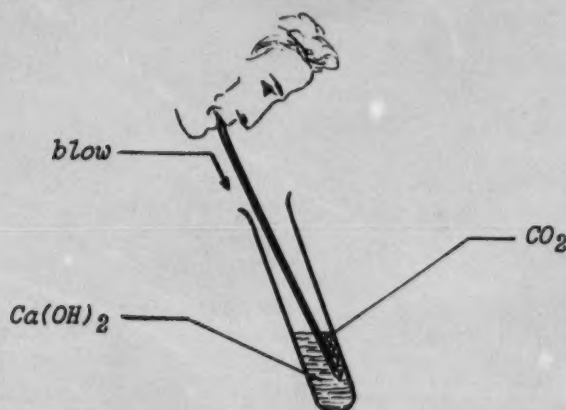
The liquids could stay layered on top of each other, firstly because one is lighter than the other (smaller in density), and secondly because they are insoluble in each other: the carbontetrachloride is *immiscible* with water, and the ether is also insoluble in water. But ether can dissolve, or is *miscible* in carbontetrachloride and thus floating the first into the other would not work. Most organic liquids, like oils, gasoline, benzene, etc. except alcohols, are *not soluble* in water or *immiscible* with water.

The iodine crystal, when dropped through the layered liquid, dissolves in different degrees in each of the solvents. This is why different color intensities appear in the liquid layers.

CHEMISTRY

SOLUBILITY &
PRECIPITOUS REACTION5.10. THE DISAPPEARING PRECIPITATE

- Materials:**
1. Calcium hydroxide solution— $\text{Ca}(\text{OH})_2$.
 2. A wide test tube & a drinking straw.

**Procedure:**

1. Fill the test tube about one third with calcium hydroxide solution. If in powder form, make a saturated solution by dissolving some in warm water and filtering excess powder; use filtrate.
2. Blow through the straw into the calcium hydroxide solution until a precipitate is formed (cloudy solution).
3. Now continue blowing into the cloudy liquid until the liquid clears up again: the cloud is blown away!

Questions:

1. What is the reaction that forms the precipitate?
2. In general, why and when is a precipitate formed?
3. What made the formed precipitate disappear?
4. When is a precipitate or solid powder in a liquid invisible?
5. Can you name other precipitous reactions?

Explanation:

By blowing into the solution, we were adding carbon dioxide gas to it. The reaction is as follows: $\text{CO}_2 + \text{Ca}(\text{OH})_2 = \text{CaCO}_3 + \text{H}_2\text{O}$, where the calcium carbonate formed is the precipitate. Although this precipitate is in the form of a milky or cloudy substance, it is still a deposit of solid material. This is apparent when the blowing is ended at this stage and the test tube left standing for a while. A precipitate will then collect at the bottom of the test tube.

By continuing the blowing, more carbon dioxide is added to the precipitate, resulting in the reaction: $\text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2 = \text{Ca}(\text{HCO}_3)_2$, which is calcium bicarbonate, and this substance is soluble in water.

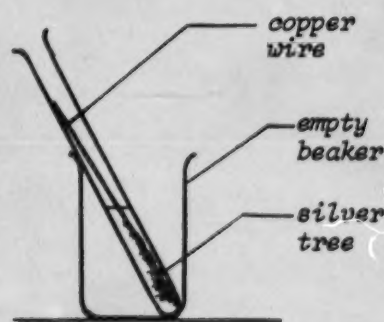
In general, a precipitate is formed when the compound formed has a low solubility in water. When this solubility is increased, either by raising the temperature or by changing the compound itself, it goes back into solution and becomes invisible (clear liquid).

CHEMISTRY

REPLACEMENT REACTION

5.11. MAKE A SILVER TREE

- Materials:**
1. A thick solid copper wire (about 10 cm long).
 2. Silver nitrate solution-- AgNO_3 .
 3. A test tube or when available: petrie dish & overhead projector.

**Procedure:**

1. Strip the insulation off a heavy electric wire.
2. Place about 10 ml of AgNO_3 (silver nitrate) in a petrie dish, or in the test tube (when dish & overhead projector are not available).
3. Put the dish on the overhead projector and slant the projector towards the screen by placing some books under the far end.
4. Place the copper wire in the dish, such that the projection shows up vertically on the screen (or insert the wire in the test tube).
5. Let students observe closely when doing the reaction in a test tube, but they may not jar or touch the test tube.

Questions:

1. What did you observe on the screen or in the test tube?
2. What is the 'tree' composed of?
3. What specific reaction took place?
4. What would happen if the test tube were jarred or touched?
5. What caused the liquid to turn blue?

Explanation:

The reaction that takes place in the petrie dish or test tube is as follows: $\text{Cu} + 2 \text{AgNO}_3 = \text{Cu}(\text{NO}_3)_2 + 2 \text{Ag}$. The silver precipitates out of the solution but clings to the copper wire, which gives the illusion of a growing tree. The reaction occurs because copper has a larger tendency to go into solution than silver. As the copper goes into solution, it forms copper ions, which are responsible for the blue color of the liquid. The longer the copper is left in the liquid, the more copper is going into solution, thus the more copper ions are formed and the deeper blue the liquid gets.

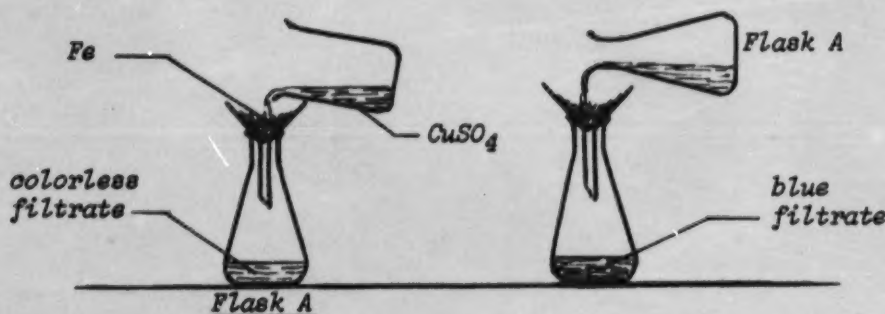
The silver, which is deposited along the wire, is just hanging loosely on it and a very slight disturbance (jarring of the container) will send the silver crashing down.

CHEMISTRY

REPLACEMENT REACTION

5.12. THE CONFUSED BLUE SOLUTION

- Materials:**
1. Dilute copper sulfate solution & dilute HCl.
 2. Course iron filings (steelwool will also do).
 3. Two small Erlenmeyer flasks.
 4. A funnel and filter paper.

**Procedure:**

1. Place a filter paper in the funnel and about half a teaspoon of iron filings or a wad of steelwool on it (do not show this to students).
2. Put about 1 ml of dilute acid in flask A.
3. Place the funnel on flask A and pour slowly the copper sulfate solution through the filter (the filtrate should come through colorless).
4. Move the funnel now to flask B and pour the filtrate through the filter paper again (the filtrate should become blue again).

Questions:

1. What made the blue color disappear in the first filtrate?
2. What do you infer would be in the funnel?
3. Can we filter out the blue color of copper sulfate?
4. What made the blue color reappear in the second filtrate?
5. What is actually responsible for the blue coloring?

Explanation:

The replacement reaction during the first pouring of the copper sulfate solution through the filter is as follows: $\text{CuSO}_4 + \text{Fe} = \text{FeSO}_4 + \text{Cu}$. Copper sulfate + iron = ferrous sulfate + copper. It is the replacement of the copper ion in the solution with ferrous ions that makes the solution colorless. With the acid in the first filtrate, and pouring this the second time through the filter, we get the following reaction: $\text{Cu} + 2 \text{HCl} = \text{CuCl}_2 + \text{H}_2$. The copper is transformed into the copper ion again and this ion is responsible for the blue color in the liquid.

The first reaction occurs because iron has a greater tendency to go into solution or to form ions compared to copper, thus iron replaces the copper, and the copper ion is transformed into the copper metal, which is retained by the filter paper. Ions will pass through filter paper, whereas solid metal particles will not.

CHEMISTRY

CATALYTIC REACTION

5.13. THE FIERY WATER

- Materials:
1. An asbestos plate or evaporating dish.
 2. A medicine dropper, mortar and pestle.
 3. Aluminum powder and iodine crystals.

Procedure:

1. Grind the iodine crystals (about a teaspoon full) in the mortar.
2. Take about the same amount of aluminum powder (make sure that the aluminum powder is dry, otherwise heat in oven before using).
3. Mix the two dry powders on the asbestos sheet or in the evaporating dish with a spatula and make a small indentation in the heap.
4. Place the asbestos plate or evaporating dish under an exhaust hood or outdoors, and add just one drop of water to the mixture of powders (use the medicine dropper)
5. Stand back and observe!

Questions:

1. Why do the iodine crystals have to be finely ground?
2. Why do the reagents have to be dry?
3. What function does the water have in this reaction?
4. Would the two substances react without the water?
5. Where in daily life does water speed up a reaction like this?

Explanation:

The iodine crystals have to be ground first to increase the contact surface between the two reagents. Smaller particles have a much larger surface area than the relatively larger crystals. If the aluminum powder is damp, the reaction may not succeed too well, because the moisture might take away the released heat needed to initiate the reaction. The water's function is that of a catalyst, which brings the molecules of the reagents even closer together. Heat is evolved from the first few molecules reacting, and this heat sets off the rest of the reaction.

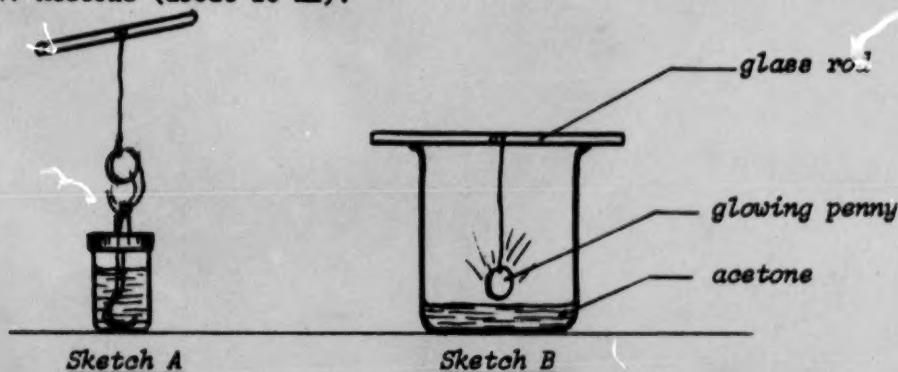
In our daily life, water speeds up the rusting process of metals when left in the damp outdoors, like bicycles, nails, etc.

CHEMISTRY

CATALYTIC REACTION

5.14. THE GLOWING PENNY

- Materials:**
1. A penny or other copper coin.
 2. Copper or other thin metal wire.
 3. A glass stirrer, small beaker, alcohol or propane burner.
 4. Acetone (about 20 ml).

**Procedure:**

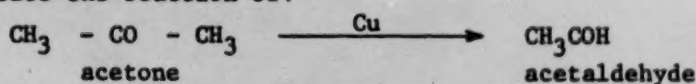
1. Make a small hole in a penny (punch a small nail through) and tie a short length of wire (about 10 cm) through the hole.
2. Wind the other end of the wire around the middle of a glass stirrer and heat the coin in an alcohol or propane flame until red hot (Sketch A).
3. Immediately after heating, hang the coin about 3 mm above the acetone level in a beaker (check this level before heating the coin, by rolling more or less windings around the glass stirrer--see Sketch B).
4. Observe the glowing penny in the dark.

Questions:

1. What made the penny glow in the flame?
2. What made the penny glow in the beaker?
3. Would the penny glow if it was hanging higher above the acetone level?
4. How high can the coin hang and still have it glowing?
5. How long will the penny stay glowing?
6. Would other metals do the same when hung above the acetone?

Explanation:

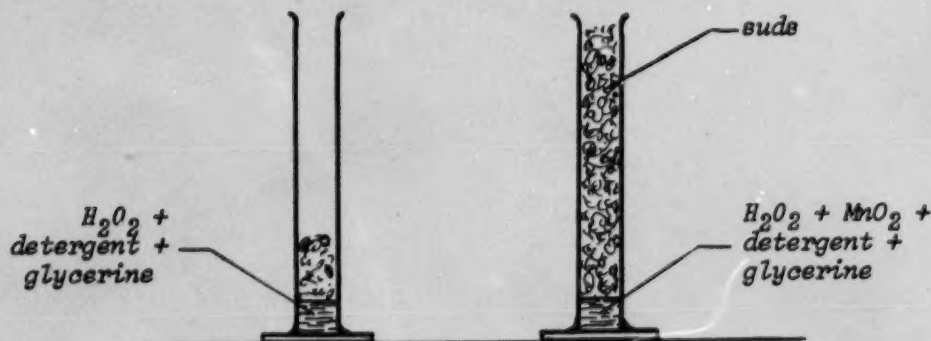
Holding the penny in the flame makes it so hot that it gives off a red glow. While the temperature of the penny is still high, it can speed up or facilitate the reaction of:



without participating in the reaction itself. Copper functions as a *catalyst* for the above reaction. The reaction is *exothermic*, thus it produces heat, which keeps the penny glowing. The glowing will stop only when all the acetone has evaporated. No other metal is as efficient a catalyst as copper for this particular reaction.

5.15. THE RISING SUDS

- Materials:
1. Two tall cylinders or narrow jars.
 2. Liquid detergent, glycerine, hydrogen peroxide (H_2O_2), manganese dioxide (MnO_2).
 3. Two long stirrers (long straws will do).

Procedure:

1. Place about 10 ml of hydrogen peroxide and 5 ml of detergent, and about 5 ml of glycerine in each cylinder.
2. Add a pinch of MnO_2 to one of the cylinders and stir the mixture in both cylinders with the long stirrers.
3. Observe the difference in height of the produced suds in the two tall cylinders.

Questions:

1. In which of the two cylinders did the suds rise higher?
2. What causes the suds to go up higher in one of the cylinders?
3. What do we need to make soap bubbles?
4. What function does the peroxide have in this reaction?
5. What do the MnO_2 and the glycerine do?
6. Would the suds rise just as high without the stirring?
7. What other substances might be used in place of MnO_2 ?

Explanation:

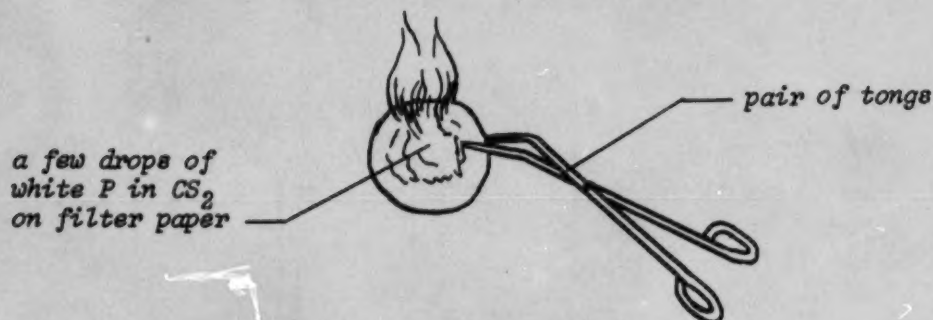
The detergent functions like the soap when blowing soap bubbles. By adding some glycerine to the detergent, the surface tension of the liquid is increased, and the bubbles will stay longer before collapsing. In order to get suds in a soap solution when blowing bubbles, we need to blow through a straw into the detergent mixture. In this case we do not need to blow. Where are we getting the gas to blow the bubbles from? The gas is supplied by the hydrogen peroxide, which decomposes into water and oxygen. The MnO_2 acts as a catalyst for this oxygen producing reaction. It does not partake in the reaction, but only facilitates it. This means that the properties of MnO_2 before and after the reaction are unchanged. Rust and dirt particles or ashes could replace the MnO_2 .

CHEMISTRY

SPONTANEOUS COMBUSTION

5.16. THE CHEMICAL FLAG

- Materials:
1. A pair of tongs, a filter paper.
 2. A test tube and tube holder.
 3. White phosphorus and carbon disulfide.

Procedure:

1. Cut a small piece of white phosphorus off a stick (do not touch the phosphorus with your fingers).
2. Place the piece of phosphorus in about 5 ml of carbon disulfide (CS_2) in a test tube.
3. After all the phosphorus has dissolved, pour a few drops of the solution on a filter paper which is held with a pair of tongs.
4. Wave the filter paper slowly in the air (like waving a flag): let students observe the 'chemical flag' catching fire!

Questions:

1. Why does white phosphorus have to be kept under water when it is stored?
2. Why is it dangerous to touch white phosphorus with the fingers?
3. At what moment did the flame burst?
4. In what state is the phosphorus spread on the filter paper?
5. What is the phosphorus reacting with?
6. Is the reaction endothermic or exothermic?

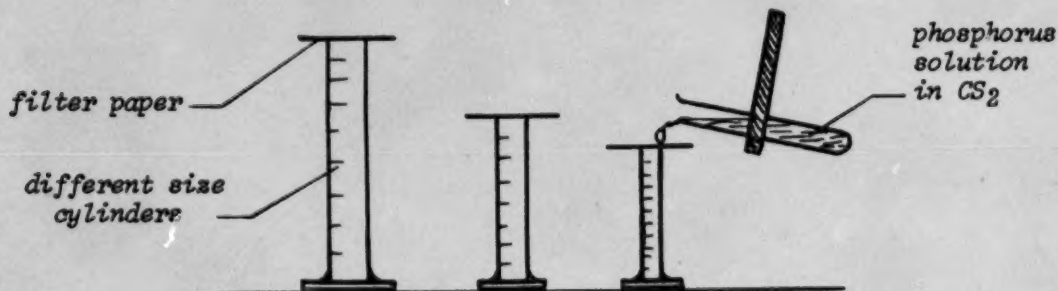
Explanation:

White phosphorus is kept under water when stored, because it would otherwise react with the oxygen in the air. By dissolving the phosphorus in carbon disulfide, it is dispersed in atomic particles (*status nascendi*). This makes the phosphorus much more reactive, and as soon as the solvent (carbon disulfide-- CS_2) is evaporated, the finely dispersed phosphorus that is left on the filter paper reacts with the oxygen in the air. As this reaction: $4\text{P} + 5\text{O}_2 = 2\text{P}_2\text{O}_5$ is exothermic, the evolved heat kindles the paper and bursts into flame.

This is the reason why it is dangerous to get the solution on the skin or any other combustible material. When accidentally dropped on the skin, it should be washed off immediately with soap and water.

5.17. THE BARKING DOG

- Materials:**
1. Three or four different size cylinders.
 2. A test tube and tube holder, & medicine dropper.
 3. Filter paper or paper towel pieces.
 4. White phosphorus (P), and carbon disulfide (CS_2).

**Procedure:**

1. Cut a piece of white phosphorus (hold phosphorus with a pair of tongs) and dissolve it in about 10 ml of CS_2 in the test tube.
2. Hold the test tube with the test tube holder and do not touch or spill the liquid (wash off immediately when spilled accidentally).
3. Place a filter paper on each of the cylinders, then carefully place five drops of the phosphorus solution on each of the filter papers (use a long-stemmed medicine dropper).
4. Move the original phosphorus solution away from the cylinders, stand back and observe the cylinders.

Questions:

1. Where did we get the lowest "bark"? Where the highest?
2. What was causing the small explosions?
3. What did we need to have in the cylinders for it to cause an explosion?
4. Would CS_2 gas be lighter or heavier than air?
5. What initiated the first spark for the explosions?
6. What should you do to the cylinders when repeating the demonstration?

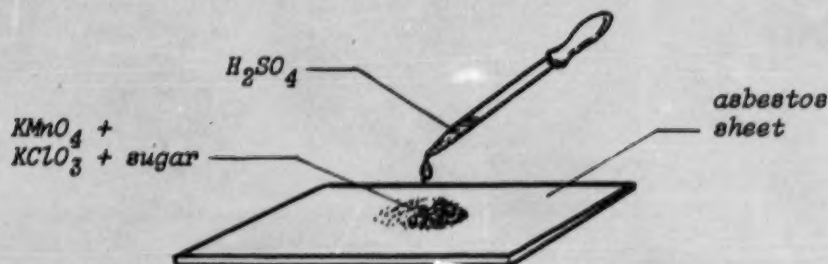
Explanation:

The white phosphorus dissolves in the carbon disulfide and is dispersed throughout the liquid in atomic form. When a few drops of the solution are poured on the filter paper covering the cylinders, the solvent (CS_2) evaporates and leaves the phosphorus behind in *status nascendi*, which means in atomic state. This state is much more reactive than when it is in the molecular state. Thus the phosphorus atoms react immediately with oxygen from the air. This is an exothermic reaction and the temperature exceeds the kindling point of the paper. This spontaneous combustion forms the first spark, which sets off the explosion of the CS_2 and air mixture in the cylinders. The different heights in the cylinders produce the high and low pitches in the "barks", the tallest giving the lowest "bark".

CHEMISTRY

STRONG OXYDANTS
SPONTANEOUS COMBUSTION5.18. COLOR THE FLAMES

- Materials:**
1. A mortar and pestle, medicine dropper.
 2. Four asbestos sheets or evaporating dishes.
 3. Potassium permanganate (KMnO_4), potassium chlorate (KClO_3), fine sugar, concentrated sulfuric acid (H_2SO_4), barium- (Ba), strontium- (Sr), copper- (Cu), and sodium- (Na) nitrates or chlorides.

**Procedure:**

1. Grind about half a teaspoon full of KMnO_4 in the mortar and put it aside on a piece of paper.
2. Do the same with half a teaspoon full of KClO_3 , put it aside and grind a full teaspoon of fine sugar (or sugar crystals).
3. Mix all three powders very carefully in the mortar (do not apply pressure on the pestle; heat of friction might set off the reaction!) and divide the mixture into four small heaps on the four separate asbestos sheets (or evaporating dishes).
4. Put a pinch of each of the salts containing the element Ba, Sr, Cu, and Na on the heap and mix it in well with the powder.
5. Place with a stretched-out arm (using the dropper) one drop of concentrated sulfuric acid on one heap of mixture at a time (this is most dramatic in a darkened room).

Questions:

1. What reaction is taking place?
2. What color did each of the flames give?
3. What caused the different colors in the flames?
4. What purpose did the drop of sulfuric acid have?

Explanation:

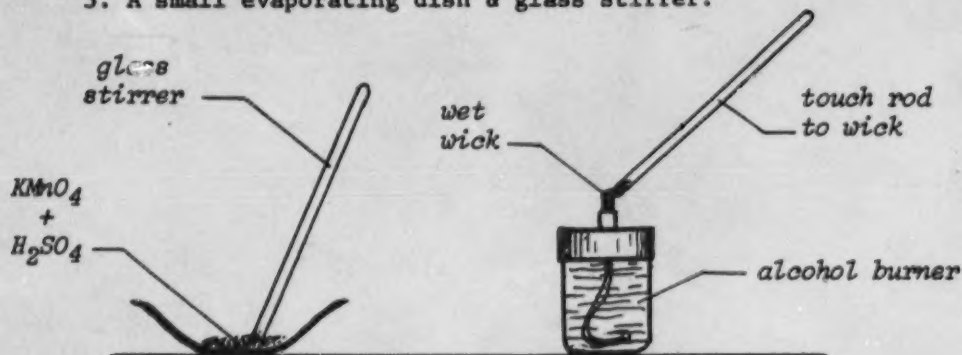
The drop of concentrated sulfuric acid reacts mainly with the sugar in the mixture and releases heat. This heat triggers the decomposition of KClO_3 and KMnO_4 , which produce oxygen in *status nascenti* (atomic form). This very active oxygen combines with the sugar and supplies the needed agent for the burning process.

The different ions of Barium, Strontium, Copper and Sodium produce the following colors respectively in the flame: yellowish green, red, bluish green, and yellow. These salts are very much used in the fire cracker industry in coloring the different fire crackers.

CHEMISTRY

EXOTHERMIC REACTION
SPONTANEOUS COMBUSTION5.19. THE MAGIC WAND

- Materials:
1. Potassium permanganate & concentrated sulfuric acid.
 2. Mortar & pestle, alcohol burner.
 3. A small evaporating dish & glass stirrer.

Procedure:

1. Grind about half a teaspoon of $KMnO_4$ (Potassium permanganate) in the mortar with the pestle, and transfer it to the evaporating dish.
2. Make sure that the alcohol burner's wick is soaked and wet with the alcohol by turning the burner upside down.
3. Mix a few drops of concentrated sulfuric acid with the $KMnO_4$ in the evaporating dish.
4. Turn the glass rod into the 'magic wand': touch the wick of the alcohol burner with the rod end that was dipped in the mixture.
5. The spontaneous lighting of the alcohol flame may be repeated as many times as needed.

Questions:

1. Why did the potassium permanganate have to be finely ground?
2. What made the alcohol burner's wick burst into flame?
3. What is the reaction that occurred between the mixture of potassium permanganate + H_2SO_4 and the alcohol?
4. Why did the wick have to be soaking wet with alcohol?
5. What other substances would also burst into flame when touched with the mixture of $KMnO_4$ and H_2SO_4 ?

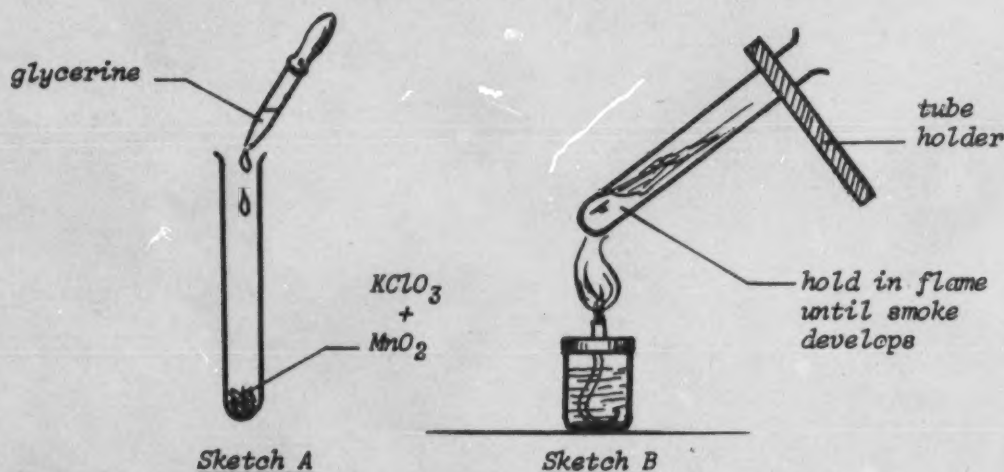
Explanation:

The potassium permanganate had to be ground to increase its surface area. This compound is a very strong oxydant, just like concentrated sulfuric acid is. When the two are mixed, heat is produced and oxygen atoms are released, which attack any material in its neighborhood that can be oxydized. The reaction is as follows: $2 KMnO_4 + H_2SO_4 = K_2SO_4 + 2 MnO_2 + H_2O + 3 O_n$; this oxygen in status nacendi is very reactive, and attacks easy oxydizable substances like: alcohols, sugars, and other carbohydrates. In the process of oxidation, much heat is being released--*exothermic*, reaching a temperature above the kindling point of alcohol. This causes the alcohol to burst into flame.

CHEMISTRY

EXOTHERMIC REACTION
SPONTANEOUS COMBUSTION5.20. THE ROCKET EXHAUST

- Materials:
1. An alcohol burner, test tube and holder.
 2. A medicine dropper, a scopula.
 3. Potassium chlorate (KClO_3), glycerine, and MnO_2 .

Procedure:

1. Place a small amount of potassium chlorate (KClO_3) and a scopula tip of manganese dioxide (MnO_2) in the test tube and mix by shaking.
2. Hold the test tube vertical and let 3 - 4 drops of glycerine fall on the powder (use a medicine dropper--see Sketch A).
3. Hold the test tube (with the holder) above an alcohol or small Bunsen flame, just until the moment that smoke develops, then remove from flame.
4. Observe the test tube and the sudden burst of flame.

Questions:

1. What reaction takes place in the test tube?
2. What purpose or function do each of the reagents have?
3. Why was it necessary to heat the mixture?
4. Why was it heated only until it started to smoke?
5. If the test tube were suspended freely hanging horizontally from two strings, would the burst of flame move it? Which way?

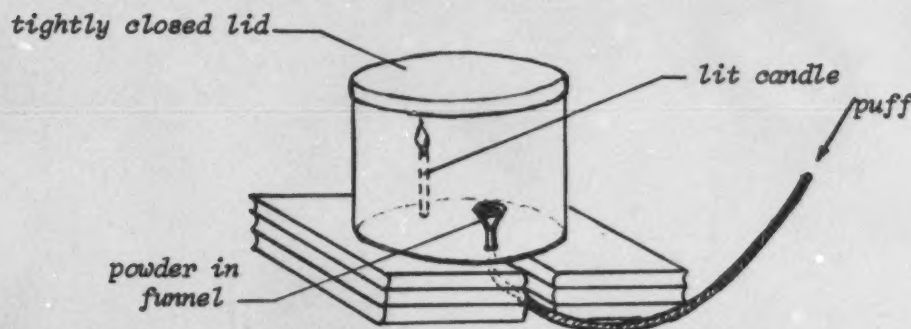
Explanation:

The potassium chlorate (KClO_3) is the source of oxygen, the manganese dioxide (MnO_2) functions as the catalyst for the decomposition of KClO_3 into KCl and O (potassium chloride and oxygen). This atomic oxygen immediately attacks the glycerine, which can easily be oxydized into alcohols, aldehydes, acids, and other gases. This reaction needs heat only in the beginning to supply the initial energy (to produce the oxygen). Once the oxygen producing reaction is going (it is extremely exothermic), the heat produced is enough to set the rest of the glycerine into flame.

CHEMISTRY

EXOTHERMIC REACTION
COMBUSTION5.21. THE ANGRY BUCKET

- Materials:
1. A syrup bucket or any can with a tightly fitting friction lid.
 2. A small funnel & rubber tubing (1 m).
 3. A 15 cm candle & small piece of tissue paper.
 4. Lycopodium powder or corn starch.

Procedure:

1. Punch a hole in the bottom of the bucket (somewhat to the side) to fit the funnel stem (with the rubber tubing attached).
2. Set the bucket on two stacks of books to allow the funnel stem to protrude below the bottom (see Sketch).
3. Place a single thickness of tissue paper in the funnel mouth to support a teaspoon of lycopodium powder or corn starch.
4. Attach the candle on the opposite side of the bucket from the funnel and light it.
5. Close the bucket lid firmly and blow a sharp puff through the rubber tube (make sure you are demonstrating it under a sturdy ceiling and away from the lights!).

Questions:

1. What made the bucket blow its top?
2. What is the purpose of the burning candle?
3. What reaction occurred inside the bucket?
4. Did all of the powder react? How do we know?
5. What other powders could we use in place of lycopodium?
6. Where do we find examples of this phenomenon in daily life?

Explanation:

At the moment that the powder was blown into the bucket, it was spread finely throughout the space and mixed with the existing air. As the powder consists of combustible hydrocarbons, it forms an explosive mixture with the oxygen in the air, and the lit candle is there to trigger the explosion. Most of the powder reacted with the oxygen to form CO_2 and water vapor. These are gases, and their sudden production suddenly increased the pressure inside the bucket, resulting in blowing the bucket's top.

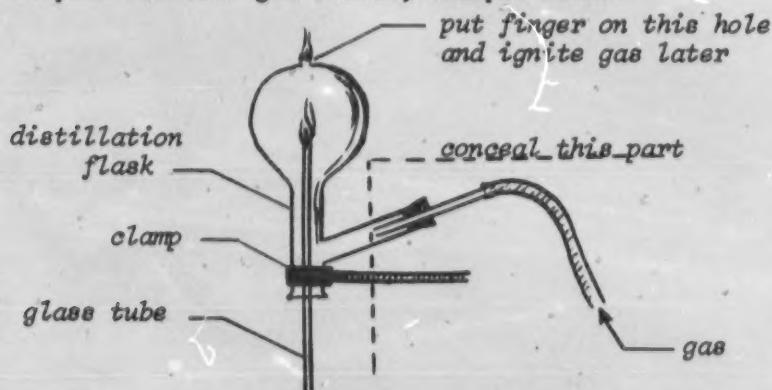
This phenomenon is encountered in coal mines full of coal dust, and when someone carelessly strikes a match an explosion is triggered.

CHEMISTRY

COMBUSTION

5.22. THE AIR-BURNING FLASK

- Materials:**
1. A distillation flask (with a small hole in the bottom).
 2. Glass tubing (25 cm long) & a 1-hole stopper.
 3. A glass tube (10 cm long) & 1-hole stopper (fits on side arm).
 4. Propane or earth gas source, clamp & stand.

**Procedure:**

1. Make a small hole in the bottom of the distillation flask by heating the flask with a torch and pushing the back end of a file or other sharp tool through the red hot glass.
2. Set the flask up as pictured in the sketch with the gas valve closed (conceal the gas connection by covering it with cardboard).
3. Open the gas valve, keeping a finger over the hole in the bottom of the flask until the gas flows out through the glass tube (check smell).
4. Ignite the gas coming from the glass tube, then release the finger holding the hole at the top of the apparatus (flame will travel up and continue to burn inside the flask).
5. Ignite the unburned gases coming out of the top hole.

Questions:

1. Is it air that burns in the flask?
2. If the top flame is a gas flame burning in an air atmosphere, how can you describe the flame in the flask?
3. What would happen if we turned the whole apparatus upside down?
4. Why is the gas only burning at the end of the tube in the flask?

Explanation:

This demonstration shows students that gas fuel cannot burn without the presence of air. The flame inside the flask is only burning at the end of the glass tube, because that is where air is present, and that is the only place where air is continuously being supplied. There is not enough air supplied to burn all the gas issued to the flask, and whatever is in excess can be burned off at the top like a regular flame coming directly from the gas supply (source).

When the whole apparatus is turned upside down, the flames are switched around: the bottom hole supplies air for the flame inside the flask and the excess gas will burn at the end of the tube.

SECTION II

ENERGY

This section consists of seven chapters dealing with the different types or forms of energy and the transformation from one into the other. Each of the chapters contains demonstrations that can be used to start off lessons dealing with the sources of energy, heat, magnetism, static and current electricity, light and sound.

Chapter 6 deals with how heat compares with temperature, heat of fusion and vaporization, the sources of energy: chemical, mechanical, heat energy, and nuclear energy, and how they can be transformed from one into the other. It also deals with potential versus kinetic energy.

Chapter 7 deals with heat and how it travels. It moves from one place to the other by conduction in solids, by convection in fluids, and by radiation through fluids and vacuums. Heat makes solids, liquids, and gases expand.

Chapter 8 contains demonstrations to show the characteristics of magnets, the nature of magnetism, and the rules of magnetism. The construction of simple compasses, the showing of magnetic lines, and magnetic induction are dealt with in this chapter.

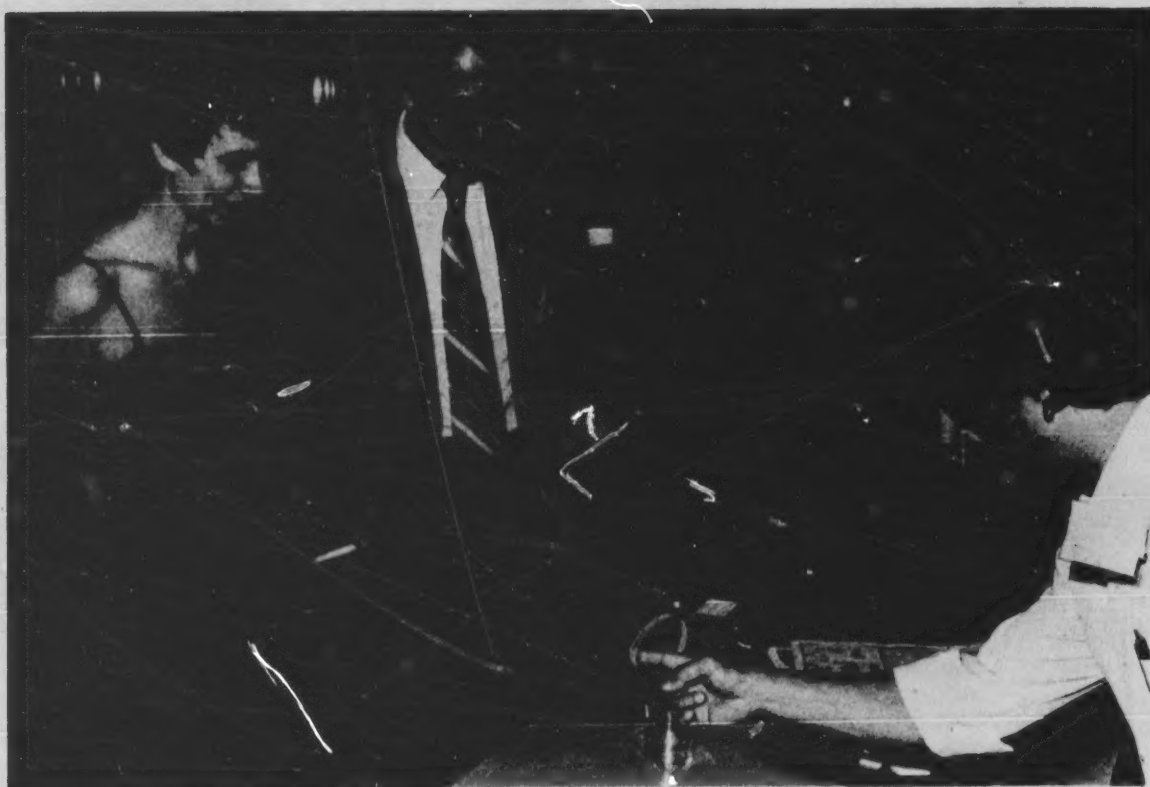
Chapter 9 should be used when dealing with static electricity. It deals with the attraction of uncharged objects, the positive and negative charges and how they attract or repel each other, the induction of static charges, and the storage of static charges in capacitors.

Chapter 10 deals with current electricity. The discrepant events can be used to start lessons in conductivity, circuits, sources of electricity, and electromagnetism.

Chapter 11 contains discrepant events to initiate lessons dealing with light, its reflection, refraction, and defraction properties.

Chapter 12 deals with sound and its properties: the medium of travel, how loudness and pitch are influenced, the nature of resonance, and its velocity in air.

In Science Teaching



a Demonstration
is Ten Thousand Words !

CHAPTER 6

WHAT FORMS OF ENERGY ARE THERE ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

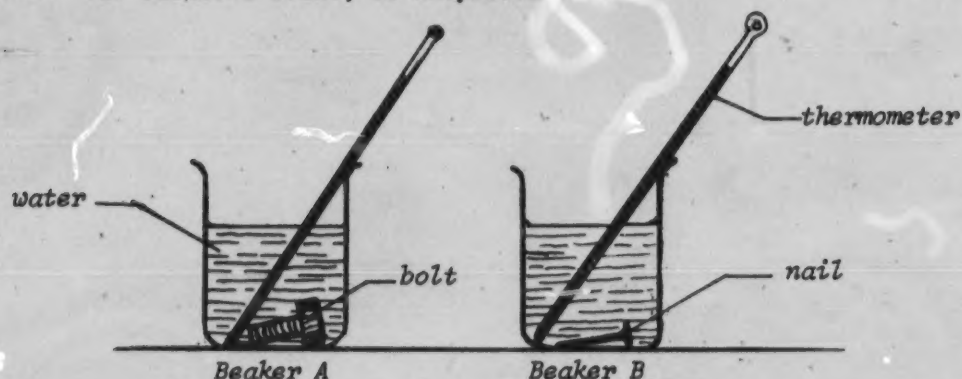
- The ability to hold heat depends on the mass and material of the object.
- Temperature is a measure of how hot or cold an object is.
- Heat is required to change a solid into a liquid, a liquid into a gas, or a solid into a gas.
- Energy can be developed from chemical, mechanical, or nuclear sources.
- All forms of energy can be transformed from one into the other.
- All forms of energy can be traced back to solar energy.

ENERGY

HEAT vs TEMPERATURE

6.1. THE HOT BOLT

- Materials:**
1. A heavy steel bolt, a small iron nail.
 2. Two identical beakers, two thermometers.
 3. One beaker or tin can (to boil water in).
 4. A pair of tweezers or tongs.
 5. Burner & stand, or hotplate.

Procedure:

1. Place the bolt and nail together in a beaker or tin can in about 100 ml of water, heat over burner or hotplate and bring to a boil.
2. Pour 100 ml of water in each of the two identical beakers and read their temperature off with the thermometer.
3. Transfer the bolt to beaker A and the nail to beaker B with the tong.
4. Read off the temperature in each of the beakers every 15 seconds until the temperature starts to level off (have a student assist you).

Questions:

1. What is the temperature of the boiling water?
2. What is the temperature of the bolt and nail before the transfer?
3. In which of the two beakers did the temperature rise higher?
4. Why did the water in the two beakers rise in temperature?
5. Which has a higher heat capacity, the bolt or the nail?
6. What determines the ability for an object to hold heat (heat capacity)?

Explanation:

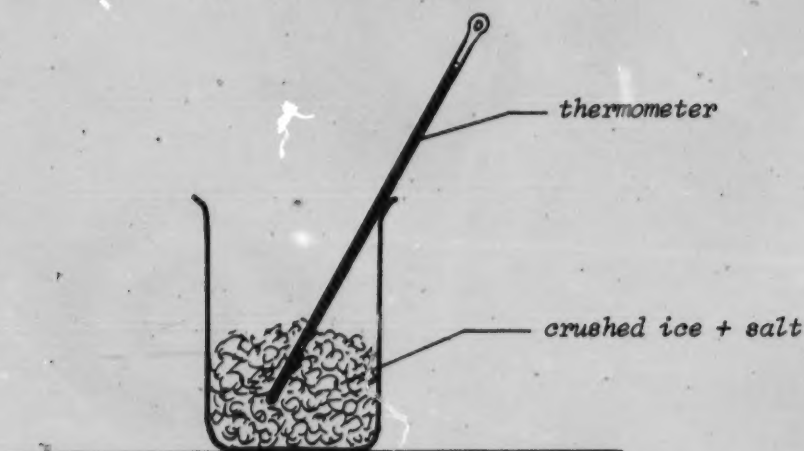
The water is boiling at 100°C , at normal pressure. The bolt and the nail that were in the same water have also the same temperature of 100°C before they were transferred to Beaker A & B, but they did not absorb the same amount of heat. The large bolt holds more heat or its *heat capacity* is higher, because it is larger in mass compared to the nail. The extra heat is enough to raise the temperature of the water in beaker A more than that in beaker B. The ability to hold heat or the heat capacity of an object is determined by its mass and the material it is made of. Temperature is a measure of how hot or cold an object or substance is in degrees Celsius or Fahrenheit. Heat refers to the total energy of the moving molecules of a substance, measured in calories or BTU's (British Thermal Units).

ENERGY

HEAT OF FUSION

6.2. MELTING ICE BELOW FREEZING?

- Materials:
1. A medium size beaker & thermometer.
 2. Common table salt, crushed ice.

Procedure:

1. (Before class starts) Fill the beaker one third full with crushed ice.
2. Pour 3 or 4 tablespoons of table salt in the center of the beaker on the crushed ice.
3. Cover this with another one third beaker full of crushed ice.
4. Now show the students the beaker with crushed ice and ask: "At what temperature will ice melt?" (Anticipated answer: 'at 0° C').
5. Insert a thermometer in the ice and let a student read it off.

Questions:

1. What is the thermometer reading of the melting ice?
2. At what temperature does ice usually melt?
3. What do you think made the ice melt below freezing point?
4. Does the melting process need heat or does it give off heat?
5. Was any heat supplied or withdrawn from the system?

Explanation:

The freezing or melting point of salt water is much lower than that of pure water. The addition of salt to the ice at 0° C causes it to melt, because salt water cannot freeze at 0° C, just as pure water does not freeze at 5° C.

The melting process decreases the temperature because melting needs heat, and as heat was not supplied to the system of melting ice, it withdraws heat from its own environment. Just as the forced evaporation of liquid without any heat supply will have a cooling effect, this decrease in temperature is a result of a forced melting process.

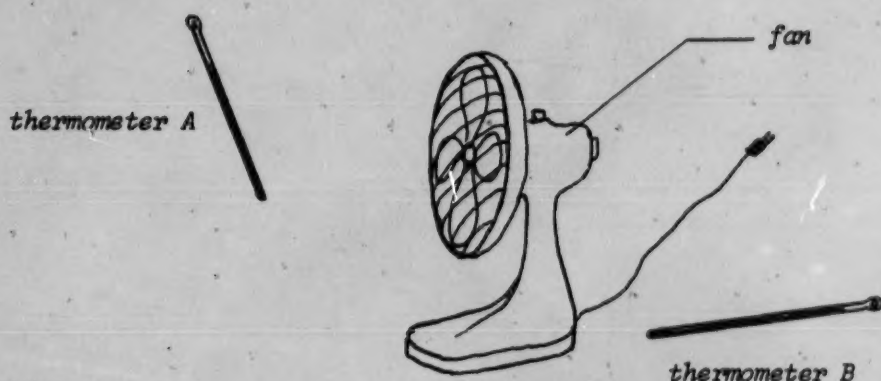
In colder climates salt is used to melt ice on slippery roads in winter.

ENERGY

HEAT OF VAPORIZATION

6.3. WARMING BREEZES

- Materials:
1. A small electric fan.
 2. Two identical thermometers.

Procedure:

1. Show the students the two identical thermometers A and B, and let two students read the temperatures of each of the thermometers.
2. Place thermometer A in the breeze of the fan and thermometer B near the fan, but not in the breeze.
3. Ask the students: "Which of the two thermometers will show a lower temperature?" (Anticipated answer: Thermometer A).
4. After leaving the fan on for several minutes and leaving the two thermometers in the two designated places, have two other students read off the two temperatures.

Questions:

1. Which of the two thermometers do you predict will show a lower temperature? The one in the breeze or the one not in the breeze?
2. What temperatures did the two thermometers show?
3. Why was there no difference in temperature?
4. What causes the cool feeling on our skin in a breeze?
5. What would you predict would happen to temperatures A and B if the bulbs of the thermometers were moistened?

Explanation:

Most of the students will predict that thermometer A will show a lower temperature. Actually, both temperatures stay the same. A very sensitive thermometer might even show that spot A (the one in the breeze) is slightly warmer than spot B, since the motor of the fan gets a little warmer and this heat is carried in the wind stream. An additional reason for it to get a little warmer is the friction of air molecules colliding with the bulb.

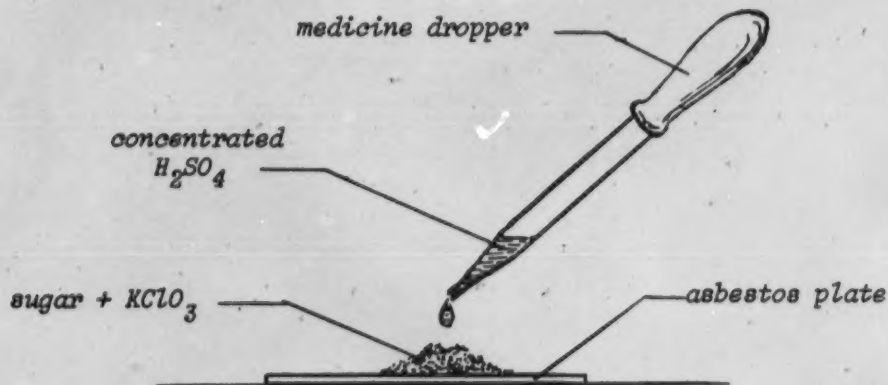
The decrease in temperature in a breeze is only caused by the evaporation of moisture. For evaporation to occur, heat is needed. When heat is not supplied, this heat of evaporation is withdrawn from the liquid's surroundings, resulting in the decrease of temperature. If the thermometer bulbs were moistened, temperature A would show up much lower.

ENERGY

CHEMICAL SOURCES

6.4. THE HOT ACID

- Materials:**
1. Potassium chlorate (KClO_3), powdered sugar, concentrated sulfuric acid (H_2SO_4).
 2. Asbestos plate or evaporating dish, medicine dropper.

**Procedure:**

1. Mix about one teaspoon of powdered sugar and one teaspoon of potassium chlorate on the asbestos plate or evaporating dish.
2. Leave the powder in a heap and make a small dent on top of the heap.
3. Suck some of the concentrated sulfuric acid in the medicine dropper (be very careful not to get any of the acid on the skin or clothing).
4. Place one drop of the acid on the heap of powder (stretch your arm as far out as possible in doing this)—do this outdoors or under the exhaust hood.

Questions:

1. What type of energy source was creating the heat?
2. Which of the two powders was actually burning?
3. What do you think was the oxygen supply for the burning?
4. What created the heat for this spontaneous combustion?

Explanation:

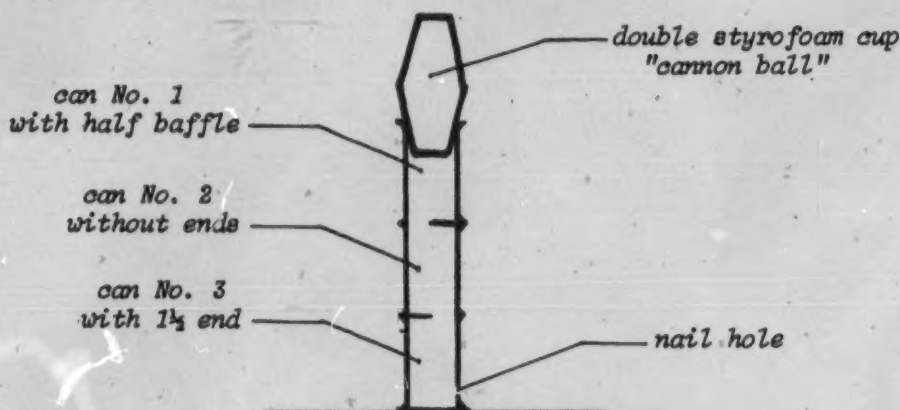
This is an example of a chemical source for heat: a spontaneous combustion. The initial heat needed for the oxygen to be released from the potassium chlorate was created by the drop of concentrated sulfuric acid and the sugar. This heat activated the release of very active oxygen in atomic form from the potassium chlorate (KClO_3). This oxygen further oxidized the sugar that was present. This further oxidation released so much heat that the sugar burst into flame. Of the two powders then, it is the sugar that was burning and the potassium chlorate provided the needed oxygen for the burning process. Most chemical reactions are releasing heat: *exothermic*. Some withdraw heat: *endothermic* reactions.

ENERGY

CHEMICAL SOURCES

6.5. THE LIGHTER-FUEL CANNON

- Materials:
1. Three empty soda-pop cans.
 2. Two styrofoam cups.
 3. Lighter fuel (or gasoline) and a match.

Procedure:

1. With a can opener cut open the ends of the soda pop cans, except for one half-end of one can (top), and the bottom and one half of the other end of the third can (bottom can).
2. Connect the three cans on top of each other with masking tape.
3. Punch a hole about 2 cm from the bottom, in the side of the bottom can about $\frac{1}{2}$ cm in diameter (use a large nail).
4. Tape the two styrofoam cups together rim to rim, and place it tightly in the top opening (see Sketch).
5. Place two or three squirts of lighter fuel in the bottom hole and shake the stack of cans (let the fuel drip along the walls), and let it stand for a few seconds. You are now ready for ignition!
6. Strike a match and hold the flame close to the bottom opening (Watch out for the double cup cannon ball!).

Questions:

1. What are the two baffles in the 'cannon' for?
2. What purpose did the shaking of the stack of cans have?
3. What kind of energy resulted from the chemical explosion?
4. What other kinds of liquids do you think could be used in place of the lighter fuel?

Explanation:

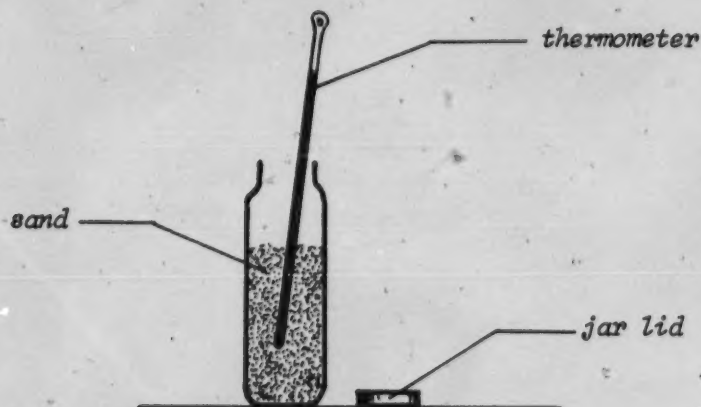
The baffles were left in the soda pop can 'cannon' to enhance the mixing of the fuel with the air in the cylinder. The shaking of the cylinder was done immediately after the fuel was injected for exactly the same reason. The better the mixture of fuel vapors and the air, the better the explosion. The chemical energy stored in the lighter fuel is transformed by the combustion into kinetic energy of the moving cannon ball. Gasoline or alcohol may be used instead of lighter fuel.

ENERGY

MECHANICAL SOURCES

6.6. WARM A BOTTLE BY SHAKING

- Materials:
1. A medium size jar with lid.
 2. Dry sand (beach sand).
 3. A thermometer.

Procedure:

1. Fill the jar about two thirds full with dry sand.
2. Push a thermometer in the sand and let one of the students read off the temperature.
3. Take the thermometer out of the jar, close the jar tightly and let the students take turns shaking the jar for 5 to 6 minutes in total (about $\frac{1}{2}$ minute each for 10 to 12 students).
4. Open the jar after the shaking, push the thermometer in the sand and let a student read off the temperature again.

Questions:

1. What were the temperature readings before and after the shaking?
2. What is the cause for the temperature to rise?
3. What type of energy was turned into heat?
4. To what type of energy as the original source can this produced heat be traced back?

Explanation:

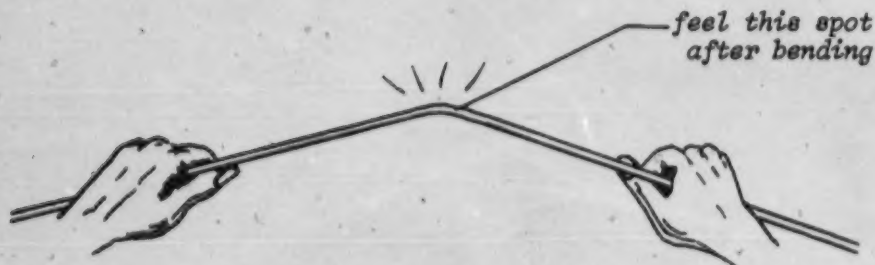
The shaking of the bottle or jar is mechanical energy, which was turned into heat. The mechanical shaking of the sand gave the sand particles kinetic energy, which caused friction between the sand particles, thus creating heat. The energy needed for the shaking of the jar was supplied by muscle power of the students. To give this energy, the students needed to eat (chemical energy), and the food the students ate came from plants and animals. The animals also needed to eat plants, and the plants in their turn obtained the energy from the sun to grow. All forms of energy can thus be traced back to *solar energy*.

ENERGY

MECHANICAL SOURCES

6.7. THE WIRE HEATER

- Materials:
1. A piece of heavy wire (coat hanger).
 2. A wire cutter.

Procedure:

1. Take a coat hanger and cut about a length of 30 cm piece off with the wire cutter.
2. Hold the two ends in each hand and bend the wire several times back and forth at the same spot.
3. Let students touch the spot that was bent, with their fingers.

Questions:

1. Did the spot you touched feel warm or cold?
2. What type of energy was used to bend the wire?
3. What made the wire heat up (explain in terms of moving molecules)?
4. Would the same happen with a plastic or wooden rod?
5. What would eventually happen if we keep bending the wire?

Explanation:

Bending the metal wire back and forth is actually putting mechanical energy from our muscles into the wire. This energy forces the molecules of metal to move faster at the bent spot and the friction of the faster moving molecules produces heat, thus causing the bent spot of the wire to feel warm to the touch. When this bending of the wire is continued, it will eventually break: this is called *metal fatigue*.

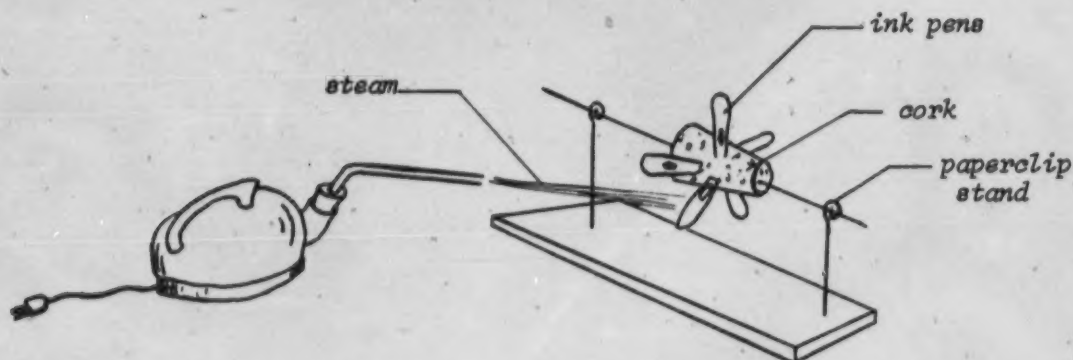
When using a plastic or wooden rod instead of a metal one, the bending can be carried on for a longer period before it breaks, because of the flexibility and elasticity of the material, unless it is bent beyond its flexibility point. The molecules here are not sliding past each other as much as in the metal wire, so that heat is not likely generated so readily.

ENERGY

HEAT SOURCES

6.8. USE HEAT TO TURN A WHEEL?

- Materials:**
1. A hot water kettle.
 2. A fitting one-hole stopper for the kettle spout.
 3. A bent glass tube fitting in the stopper.
 4. A cork, 6 old ink pens, 4 paper clips.
 5. A piece of soft wood or board.

**Procedure:**

1. Fill the electric kettle with water and plug it in.
2. Insert the bent glass tube in the one-hole stopper and cover the kettle spout with the stopper.
3. Stick the six old ink pens (or any other small metal narrow plates) in the side of the cork and set up the cork to move freely as in the sketch, with modified paperclips as a stand on the wood board.
4. As soon as the water boils, direct the steam towards the lower or upper side of the cork against the baffles.

Questions:

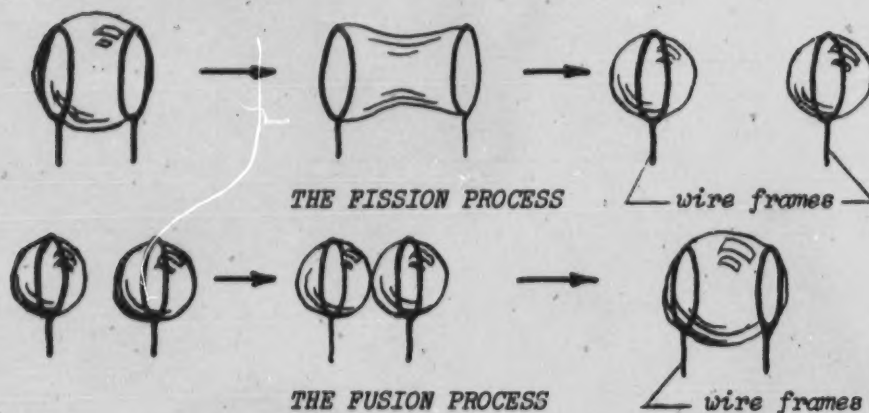
1. What is the original source of energy used to turn the wheel?
2. What forms of energy do we encounter in this event?
3. Where do we find this principle applied?
4. How is electricity produced and what could be the original form of energy that is transformed into electricity?

Explanation:

The original source of energy used is electricity for the electric kettle, which may be traced back to chemical sources or water power. The electricity is turned into heat in the heating coils of the kettle, which causes the water to boil and thus forming the steam. By leading this steam through a narrow tube, the vapor particles are pushed out with a velocity and thus gain in kinetic energy. In directing this steam flow to the scoops of the wheel, the kinetic energy is converted into mechanical energy. This finds application in the production of electricity in turning the turbo engines and in other steam engines.

6.9. FISSION AND FUSION

- Materials:**
1. Soap solution (1 pt Joy, $2\frac{1}{2}$ pt glycerine, 3 pt water).
 2. Two circular wire frames.
 3. A wide shallow tray.

**Procedure:**

1. Place the soap solution in the shallow tray and dip the two circular wire frames in the solution.
2. Blow through the wire frame and blow a bubble with a diameter a little larger than the frame, and catch the bubble between the two frames.
3. Now stretch the bubble by pulling the two frames farther apart until the bubble separates into two bubbles in each frame (fission).
4. Bring the frames and the bubbles in it together; let the bubbles press against each other until they form one large bubble (fusion).

Questions:

1. Why are bubbles always spherical in shape?
2. What is missing from this model of fission or fusion?
3. What examples can you give on nuclear energy sources in nature?
4. What are the dangers in the use of nuclear energy?

Explanation:

This demonstration with the soap bubbles is only a model for the actual process of fission or fusion. In the case of *fission*, a very heavy nucleus splits and forms medium-weight nuclei. When two light-weight nuclei combine to form heavier, more stable nuclei, it is called *fusion*. The elements that are missing in the soap bubble model, are the neutrons and the energy released during fission, and the protons and energy released during fusion.

A nuclear source of energy in nature is the sun, where four hydrogen atoms fuse into one helium atom, and in the process of fusion it releases energy in the form of sunshine.

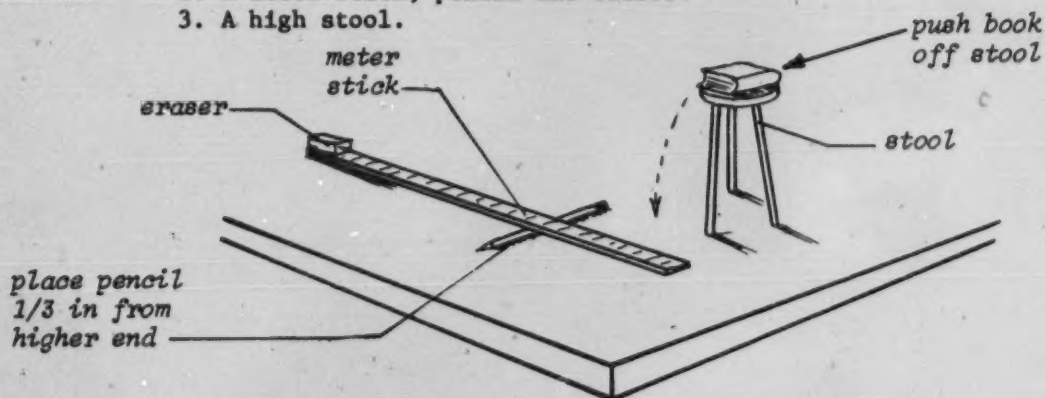
The dangers in using nuclear energy lie in radiation leakages and the doses of radiation that the human being can withstand without being harmed.

ENERGY

POTENTIAL vs KINETIC

6.10. DOES A BOOK HAVE ENERGY?

- Materials:**
1. A heavy book (encyclopedia or dictionary).
 2. A meter stick, pencil and eraser.
 3. A high stool.

**Procedure:**

1. Place a stool on the table top and put a heavy book on the stool. Ask students: "Does the book have any energy at this position?"
2. Place the meter stick on the table top about 20-30 cm in front of the stool, such that when the book is pushed off the stool, it will fall on the end of the ruler.
3. Insert a thick pencil under the meter stick, about one third from the end where the book will be falling on.
4. Place an eraser on the other end of the meter stick.
5. Push the book off the stool (and let it fall on the meter stick). Observe the eraser fly up!

Questions:

1. What kind of energy did the book have when it was lying on the stool?
When it was falling on the ruler?
2. Does the book have any energy lying on the table top?
3. What type of energy did the book impart on the meter stick?
4. What kind of energy did the eraser obtain?
5. What was the original source of energy that triggered the flying eraser?

Explanation:

When the book was lying on top of the stool, it had potential energy. As long as the book has the potential of falling towards the center of the earth, it has potential energy. Thus when it was laying on the table top after falling off the stool, it still possesses potential energy (to fall off the table and send another eraser flying). At the moment that the book was falling, this potential energy was transformed into kinetic energy, which was turned into mechanical energy of the moving meter stick, and this was imparted to the eraser, which obtained kinetic energy.

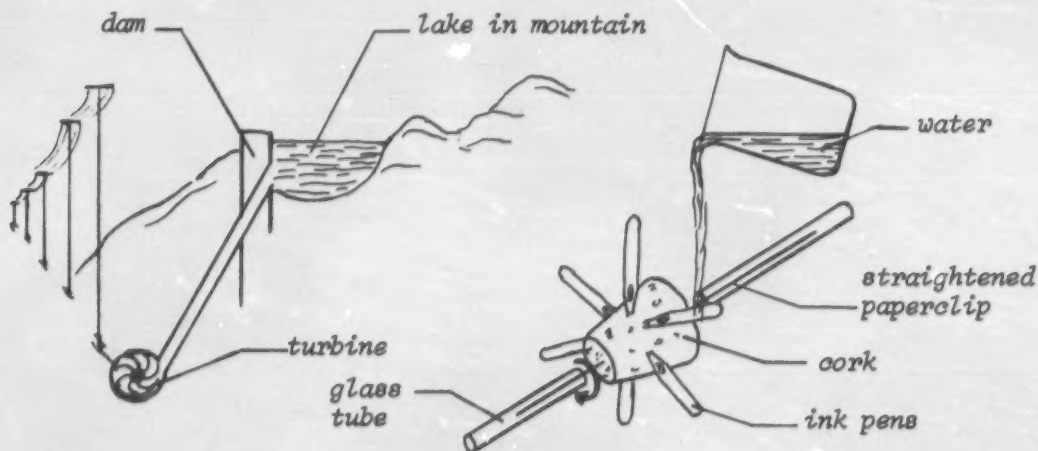
The original source of energy of this whole chain reaction was human muscle energy, which can be traced back to solar energy.

ENERGY

POTENTIAL vs KINETIC

6.11. DOES WATER IN A LAKE HAVE ENERGY?

- Materials:**
1. A large beaker, two short glass tubes.
 2. A cork, 6 old ink pens, 2 paper clips.
 3. Two clamps and two stands.

**Procedure:**

1. Push the six ink pens radially in the cork and set the materials up like in the sketch, so that the cork can rotate freely.
2. Hold the water-filled beaker above the cork and tell students: "This represents water in a lake up in the mountains".
3. Ask the students: "Does the water have energy? What kind?"
Pour the water on one side of the cork on the protruding pens (do this over a sink or a container to catch the water).

Questions:

1. What kind of energy does the water in the beaker have?
2. What kind of energy was moving the cork?
3. What is the resultant type of energy produced?
4. If the water in the beaker can be compared to the water in a lake, what can we compare the rotating cork with?
5. What kind of energy do we need to bring the water up in the beaker?
6. What type of energy is needed to fill up a lake with water?

Explanation:

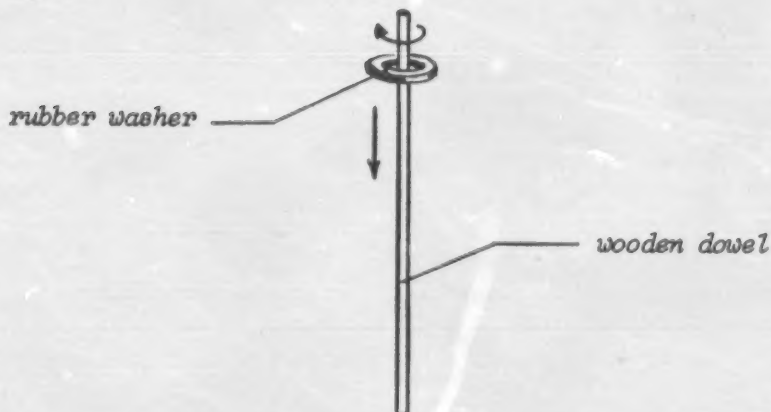
The water in the beaker, held up high, is comparable to the water in a lake up high in the mountains, possessing potential energy. The energy may be released and transformed into kinetic energy by building a dam and controlling the flow of the water. By letting the flow of water pass the turbines, represented by the cork and protruding ink pens, the kinetic energy of the water is transformed into mechanical energy, which in turn is transformed into electrical energy. This last step takes place in the generators, being rotated by the turbines.

ENERGY

POTENTIAL vs KINETIC

6.12. THE SPINNING RINGS

- Materials:
1. A 1 cm diameter wooden dowel (about 1 m long).
 2. Large rubber washers (about 2½-3 cm in diameter).

Procedure:

1. Hold the dowel vertically on the table top and the rubber washer at the top of the dowel. Ask the students: "How long will it take for the ring to drop the length of the wooden dowel?" (anticipated answer: 'A fraction of a second').
2. Give the ring a spin at the top of the dowel and time its fall. Ask: "Why is the fall not occurring in a uniform motion?" Observe the spinning and the falling speed carefully (when the falling slows down, the spinning or rotation of the washer increases).

Questions:

1. How long did it take for the spinning ring to fall?
2. What made the ring keep on spinning?
3. What kind of energy did the ring at the top of the dowel have?
4. Why did the ring spin faster after a sudden drop in height?

Explanation:

The friction between the dowel and the ring prevents the ring from dropping straight down. The faster the ring is spinning, the larger the force perpendicular to the dowel, and thus the stabler its plane of rotation. By dropping, potential energy is transferred into rotational kinetic energy. It can be shown that the rotation of the ring requires energy by spinning it on a horizontal dowel (one spin will probably spin it for a few seconds). The potential energy that the ring possessed at the top of the dowel is not completely transformed into the rotational kinetic energy, but some heat of friction has no doubt developed between the dowel and the ring.

CHAPTER 7

HOW DOES HEAT AFFECT THINGS ?

OBJECTIVES

After dealing with and studying the concepts and subconcepts in this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

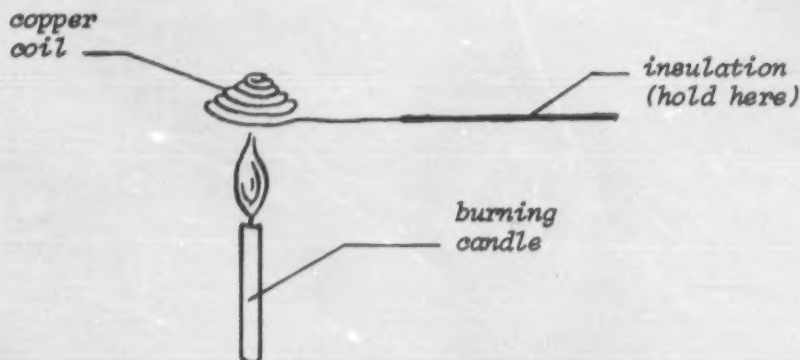
- Heat travels by conduction in solids.
- Heat travels by convection in fluids - liquids and gases.
- Heat travels by radiation in fluids and in vacuum.
- Heat makes solids, liquids, and gases expand.
- Cooling makes solids, liquids, and gases contract.
- A substance does not burn unless its kindling point is surpassed.

HEAT

CONDUCTION

7.1. THE COIL CANDLE-SNUFFER

- Materials:**
1. Insulated solid copper wire (about 30 cm)
 2. A wire stripper or knife.
 3. A birthday candle & matches.

Procedure:

1. Take the copper wire and strip $\frac{3}{4}$ of the insulation off one end (use the wire stripper or knife).
2. Make a spiralling coil of the stripped end of the copper wire.
3. Light the candle and fasten it to the table with a drop of molten wax.
4. Lower the coil over the candle flame quickly: flame snuffed!
5. Relight the candle; and now lower the coil slowly over the flame (hold it in the flame for a while), then lower the coil over the candle: flame stays on!

Questions:

1. What made the flame go out when the coil was lowered quickly?
2. Was the flame cut off from the air?
3. Why did the flame stay on after the coil was held in the flame for a longer period?
4. What was the temperature of the coil the first time compared to the second time it was lowered over the flame?
5. Why was the insulation not completely stripped off the wire?

Explanation:

In lowering the copper spiral over the flame, it was conducting the heat away from the flame. This made the surrounding of the flame suddenly drop in temperature, which made the flame go out. In other words, the temperature dropped below the *kindling temperature* of the candle wax.

When holding the coil for a longer period of time in the flame, it is heated to a higher temperature. When this hot coil is now lowered over the flame, it will not extinguish it, because the surroundings of the flame have a temperature which is higher than the *kindling point* of candle wax.

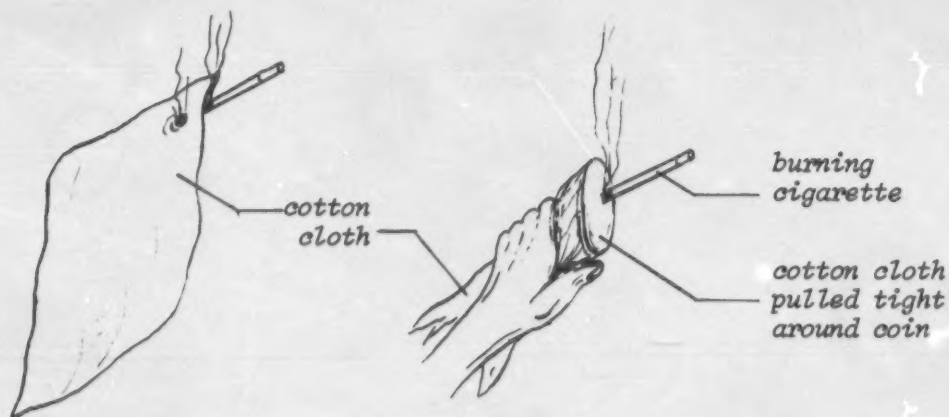
The insulation of the wire was left on at one end of the wire in order to prevent conduction of the heat to the fingers. Without insulation it would be too hot to hold the coil with the bare fingers.

HEAT

CONDUCTION

7.2. THE CHARLESS COTTON

- Materials:
1. A quarter coin or any large coin (copper is best).
 2. A piece of old cotton cloth.
 3. A cigarette and matches.

Procedure:

1. Take the piece of cotton cloth, light the cigarette and show students how easy it is to burn a hole through the cloth (in the corner of it).
2. Wrap the cotton cloth over the coin tightly and hold it in one hand.
3. With the other hand, push the lit cigarette against the cloth on the coin—cotton cannot be charred or burnt!
4. Take the cigarette off the cloth and show no charred spot on the cloth.

Questions:

1. Why was it not possible to char the cotton on the coin?
2. Why is it so easy to burn a hole in the cotton without the coin?
3. After the attempt to char the cotton, how does the coin feel?
4. Could the quarter be replaced with a penny? A nickel? An iron disc? A wooden disc? A plastic disc?
5. What temperature does the cotton have to reach in order for it to burn?
6. What was the purpose of the coin?
7. How did the heat travel away from the cotton?

Explanation:

The heat from the lit cigarette is enough to easily char or burn a hole in the cotton cloth. With the cloth drawn over a coin, however, this heat was absorbed by the coin and conducted away from the cloth. The heat of the burning cigarette disappeared into the coin, lowering the temperature of the cloth, with the result that the cloth could not be charred.

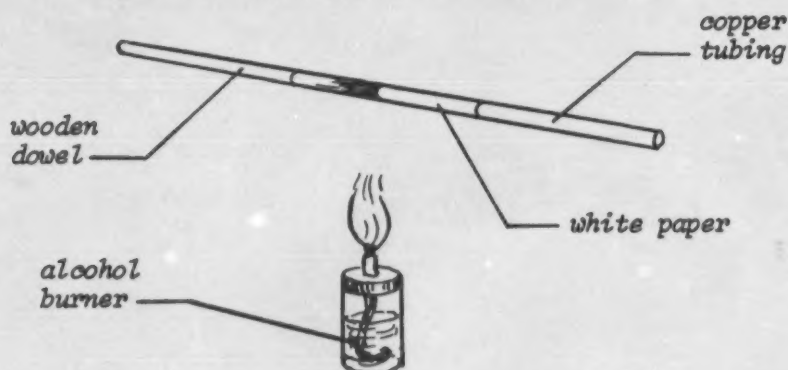
The cloth has to be held very tight over the coin in order for this demonstration to succeed. The closer the contact between cloth and coin, the better the conduction of the heat away from the cloth.

HEAT

CONDUCTION

7.3. THE SCORCHING PAPER

- Materials:**
1. A short wooden dowel (about 10 cm).
 2. A piece of copper rod or tubing (with the same diameter as the wooden dowel).
 3. Paper, cello tape, alcohol burner.

Procedure:

1. Take the wooden dowel and the copper rod (or tubing) of the same diameter, and join them together by wrapping one layer of white paper around them (use cello tape only at the end of the paper--make sure that the paper is tight against the rods).
2. Hold the metal rod and heat the piece of paper evenly over the colorless flame of the alcohol burner, by moving it back and forth above it (do not let the paper touch the flame). Continue this heating until some scorching of the paper occurs.

Questions:

1. Where did the scorching occur?
2. Why did the paper only scorch on one side?
3. Could a candle flame replace the alcohol burner?
4. Why do we need to heat the paper evenly?
5. What would happen to the paper if the copper rod were replaced by a piece of rubber tubing? Glass tubing?
6. What would the paper do if we had more than one layer of paper wrapped around the rods?

Explanation:

The copper tubing, compared to the wooden dowel, is a much better heat conductor. The heat on the copper side was therefore conducted away from the joint which was heated, whereas the heat on the wood side stayed where it was. The temperature at the wood side got much higher than that at the copper side, thus scorching occurred on the wood side.

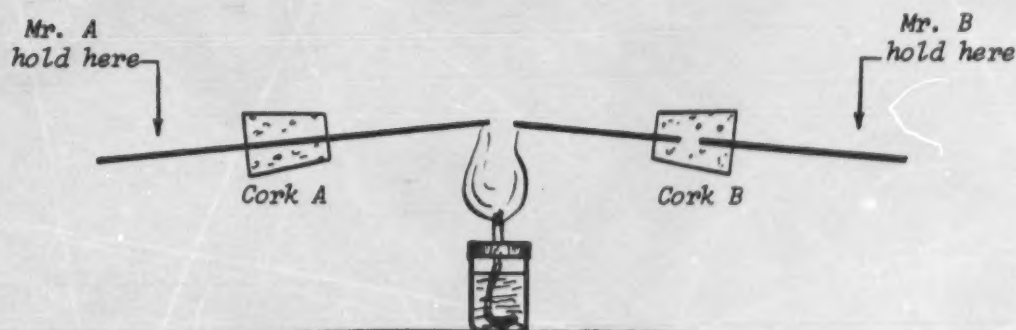
When the metal rod is replaced with less good conductors of heat, like rubber or glass, the scorching will most likely occur on both sides of the paper, as the heat build-up will take place on both sides.

HEAT

CONDUCTION

7.4. THE HEAT RACE (I)

- Materials:
1. Two small corks.
 2. One long and 2 short pieces of copper wire.
 3. An alcohol burner.

Procedure:

1. Cut the following lengths of copper wire: 10 cm, two $4\frac{1}{2}$ cm.
2. Push the 10 cm wire through one of the small corks (see Cork A).
3. Push the two short wires through each end of the other cork (Cork B).
4. Let two students hold one end of the wire and keep the other end in the alcohol burner flame. (do not reveal to the students that the wire in cork B is broken--soon Mr. A will let go of the wire!).

Questions:

1. Why did Mr. A have to let go of the wire?
2. Why can Mr. B keep on holding the wire in cork B?
3. What can you infer about the wire in cork B?
4. By what means was the heat transferred to Mr. A's fingers?
5. What would Mr. A have to do in order to be able to further heat cork A?

Explanation:

Mr. A had to let go of the wire containing cork A, because the heat from the alcohol flame was conducted to the end where the wire was held. This end eventually became too hot to hold. The students could infer about the wire in cork B, that it was made of poor-conducting metal or some other non-conductive material, or that it was broken in the cork and thus not further conducting the heat to the fingers.

In order for Mr. A to keep on holding the wire with cork A, he has to put some non-conductor of heat between the wire and his fingers. This will stop the heat conduction to his fingers and he will be able to keep holding the wire. In Mr. B's case the heat conduction was stopped in the cork, because the wire was broken in cork B.

HEAT

CONDUCTION

7.5. THE HEAT RACE (II)

- Materials:**
1. A glass rod or tube (about 20 cm long).
 2. A copper, iron, and aluminum wire (15 cm each).
 3. An alcohol burner.
 4. A candle and three paper clips.

**Procedure:**

1. Take equal lengths (15 cm) of a copper, iron, and aluminum wire and twist them together at one end.
2. Spread the other end wide out with about 120° angle between them.
3. Attach a paper clip at equal distances (10 cm) from the twisted end with a drop of melted wax (from the candle).
4. Bend the twisted end so it can hang over the glass rod.
5. Heat the twisted end over the alcohol flame and measure the time it takes for the paper clips to drop.

Questions:

1. Which of the paper clips dropped first, second, and last?
2. Which of the metals is the best heat conductor? Which the worst?
3. Which variables do we have to keep constant for this race?
4. Which are the manipulated and responding variables?
5. Would more or less wax holding the clip have any influence in the race?

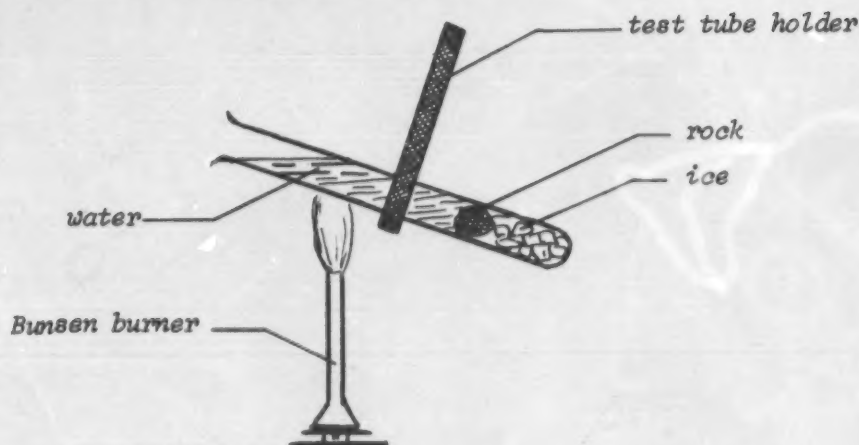
Explanation:

Although the paper clips are attached at the same distances from the twisted end and thus from the alcohol flame, they do not fall off at the same time. This is because the *thermal conductivity* of each of the metals is different. Copper has the highest thermal conductivity, then comes aluminum, and last is iron. The variables that are influencing the race are: the position of the flame, the amount of wax used to attach the paper clip, the dimensions of the wire, the distance of the paper clip from the flame, the size of the paper clip, and many more, which have to be held constant for this race. The manipulated variable is the kind of metal (this is different in the three wires) and the responding variable is the time the clip could hang on to the wire after heating was started, or the thermal conductivity of the metal. The heat is conducted from the twisted end towards the open end in each wire. The heat melts the drop of wax to which the paper clip is attached, and this latter falls off.

HEAT

CONDUCTION
CONVECTION7.6. CAN ICE-WATER BOIL?

- Materials:
1. Small ice cubes (crushed ice).
 2. A wide test tube and holder.
 3. A small weight or rock.
 4. An alcohol or Bunsen burner.

Procedure:

1. Place some ice cubes in the test tube (about 1/3 full) and put a rock or small weight on it in the tube.
2. Pour water in the tube until almost full.
3. Clamp the test tube in the tube holder and hold the upper part of the test tube in the flame of the alcohol or Bunsen burner (see Sketch), until the water boils.
4. Show students that the ice cubes are still present beside the boiling water in the top of the tube.

Questions:

1. Why did the ice not melt by the heating?
2. What is the purpose of the rock?
3. Would this demonstration work without the rock?
4. Was the water conducting the heat well?
5. Were there convection currents taking place in the test tube?

Explanation:

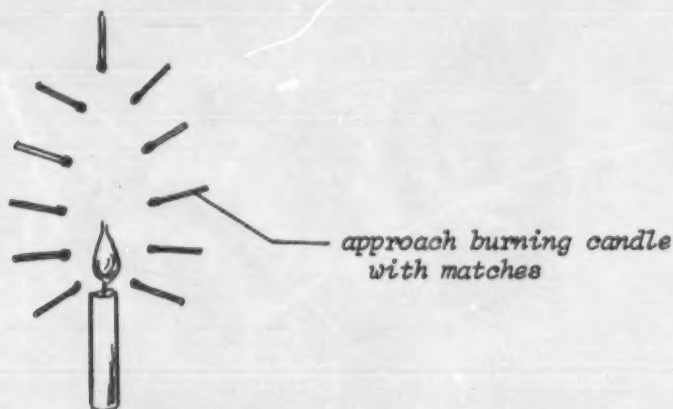
The ice is kept in the lower part of the test tube by the rock or small weight. Without the weight, the ice would float in the test tube and heating this would melt the ice first before the water can boil. By keeping the ice down in the test tube, the water in the upper part can be heated and boiled without melting the ice, because hot water is lighter than cold water. Very little convection takes place: only in the upper part of the test tube. Another reason for the ice not melting is, that water is a *poor conductor* of heat. The heat from the upper part of the test tube is therefore not conducted to the ice in the lower part of the tube.

HEAT

CONVECTION

7.7. THE CONVECTION TESTER

- Materials:
1. Candles (for each pair of students).
 2. Matches (a book for each pair of students).

Procedure:

1. Distribute a candle and a book of matches to each pair of students in the class, and instruct them to do the following points.
2. Light the candle and secure it to the desk.
3. Approach the candle flame with the match head from different angles until it bursts into flame (make sure that the flame is straight up).
4. Estimate (or measure) and record the nearest distance between the unburnt match and the flame at the different locations (see Sketch).

Questions:

1. Why can we approach the flame closer at the bottom of the flame?
2. What does the air do above the flame?
3. Why can't we come closer to the flame if we approach it with the match head from above without burning it?
4. What temperature is exceeded when the match head bursts into flame?
5. Do the match heads burst into flame at exactly the same temperature?
6. What are the variables influencing the ignition of the match heads?
7. Would a propane or Bunsen burner flame behave in the same manner?

Explanation:

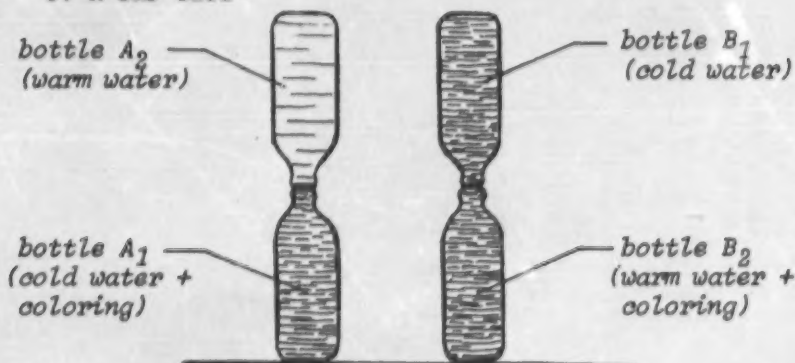
The heat from the flame creates a convection in the air, making the spot above the flame hotter than anywhere else around the flame. The reason for this is that hot air is lighter than cool air. As the spot above the flame is hotter, the match heads can approach the flame at the bottom of it much closer than at the top of the candle flame before bursting into flame. The heat reaching the match heads at the lower part of the candle flame is mostly by radiation and not convection of heat.

HEAT

CONVECTION

7.8. THE CONFUSED BOTTLES

- Materials:
1. Four empty identical soda-pop bottles
 2. Food Coloring
 3. A 3x5 card

Procedure:

1. Fill two bottles (A_1 and B_1) with cold and two bottles (A_2 and B_2) with warm water (do not reveal to students the temperature difference).
2. Color the water in bottles A_1 and B_2 with a few drops of food coloring and mix the color evenly (cover the bottle with your thumb and turn upside down).
3. Cover bottles A_2 and B_1 with a small piece of the paper card, and place them upside down on the colored bottles (one finger on the card will keep the water from spilling while turning it upside down: center the bottles A_2 and B_1 carefully over A_1 and B_2 and slip out the piece of card by holding the top bottle).
4. Let the students observe what is happening to the color.

Questions:

1. Why did the top bottle B get colored and not Bottle A?
2. Do you think the temperature of all four bottles of water was the same?
3. Which of the four bottles were warmer?
4. Does bottle A_2 ever get colored; if so when?
5. What would happen to the color if the temperature of all four bottles were the same?

Explanation:

The water in bottles A_1 and B_1 was cold and that in A_2 and B_2 was warm. Warm water is lighter in weight or less dense than cold water and thus rises. Since the warm water in B_2 was colored this water rises into the top bottle and the cold water sinks bringing with it *convection currents*. As the water in A_2 is warm and already above the cold water in A_1 , no convection is occurring in this set of bottles, and thus no coloring of the top bottle.

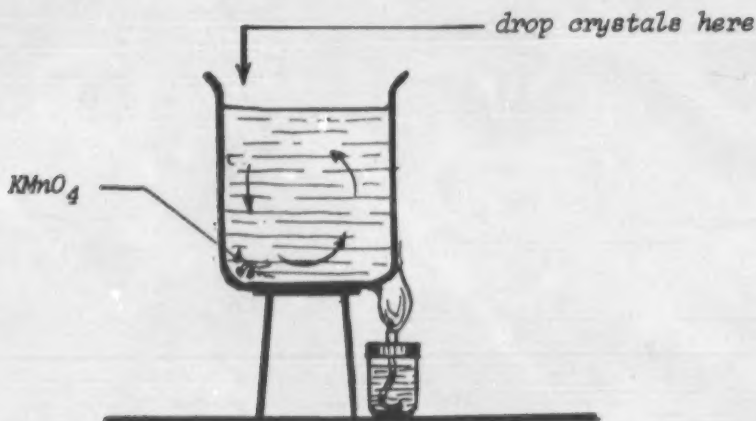
When the water temperature of this top bottle gets to be equal to that of the lower bottle, *diffusion* of the color will occur, but no *convection*. This process is much slower than convection and is caused by the constant vibration of molecules.

HEAT

CONVECTION

7.9. INTERESTING CURRENTS

- Materials:
1. A large beaker (800 - 1000 ml).
 2. An alcohol or propane burner, and tripod.
 3. Potassium permanganate (KMnO_4) or food coloring or ink.

Procedure:

1. Fill the large beaker with water and place it on the stand.
2. Light the alcohol or propane burner, but keep it away from the beaker.
3. Drop a few crystals of potassium permanganate (KMnO_4) or a few drops of food coloring close to one side of the beaker.
4. Quickly place the flame under the opposite side of the beaker, and let students observe the color movements in the water.

Questions:

1. What makes the KMnO_4 crystals sink to the bottom of the beaker?
2. What does the flame do to the water?
3. When the fluid expands, does it get lighter or heavier per unit volume?
4. When the fluid is heated, what characteristic is decreased?
5. Instead of using the flame, what could we use to achieve the same convection currents?
6. Where do we find these interesting currents in our daily life?

Explanation:

The flame of the burner is heating the water on one side of the beaker, which makes the water expand at this spot, making the water less dense. As the density here decreases, the water gets lighter per unit volume and rises. The crystals of KMnO_4 are greater in density than water and thus they sink. As the hot water on one side of the beaker rises, the cold water on the opposite side of the beaker moves down, and a convection current is created in the water. This convection current is made visible by the color in the water, which is moved along with it.

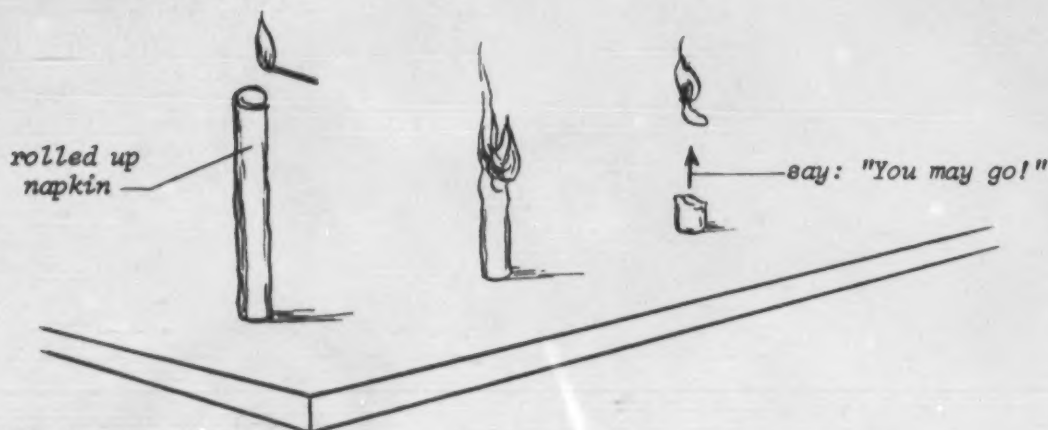
In our daily life, warm currents can occur in oceans, like the warm Gulf Stream moving up north along the American Eastern Seaboard.

HEAT

CONVECTION

7.10. THE MYSTERIOUSLY RISING NAPKIN

- Materials:**
1. A thin paper napkin (the cheapest quality, rather crisp to the touch, used to replenish refillable dispensers).
 2. Matches.

Procedure:

1. Test the napkin before the actual demonstration:
 - a. Roll the napkin in a cylinder with about 3 cm diameter and let it stand upright on the table.
 - b. Burn the napkin at the top and see whether the ashes stay together and lift off the table at the end of the burning.
 - c. If the ashes stay together and it does not rise up towards the end of the burning, try it with $\frac{3}{4}$ or $\frac{1}{2}$ of the napkin, by tearing $\frac{1}{2}$ or $\frac{1}{4}$ of it off.
 - d. Once the right kind of paper is found, you are ready for the actual demonstration.
2. Roll the napkin in a cylinder and let it stand on the table top.
3. Start to burn the napkin at the top of the cylinder. At this moment you may tell a story (about three guys who passed away and who were waiting to go into heaven at the pearly gate; St. Peter looking at the three stacked-up guys, was judging them for what they have done on earth; the first was not good enough, the second did not enough good but the third was OK and can go).
4. Just before the flame hits the table, say: "You may go!" (or whatever comment suits your own story).

Questions:

1. What made the ash shoot up in the air?
2. Why did the burning paper not rise up in the air before the flame reached the bottom?
3. Where can we see this phenomenon in our daily life?

Explanation:

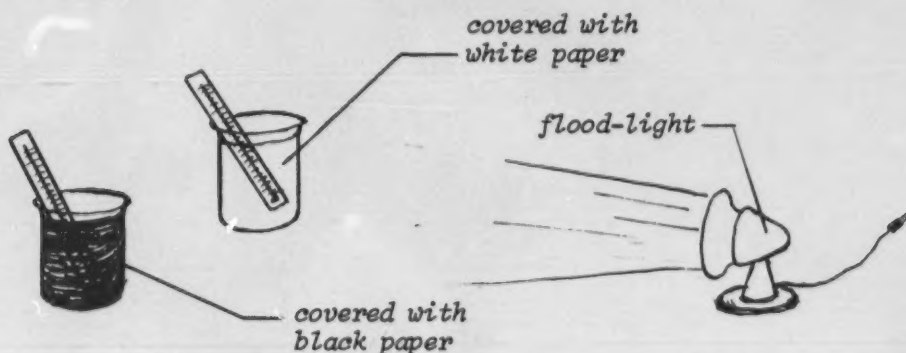
The ash content of the paper is critical in this demonstration. If the ash stays together and is light enough, it will reach the proper weight to be carried up by the convection current created by the flame.

HEAT

RADIATION

7.11. WHICH IS THE WARMER COLOR?

- Materials:
1. Two identical beakers (100 ml).
 2. Two identical thermometers.
 3. A flood-light or spot-light.
 4. A piece of white and a piece of black paper.

Procedure:

1. Wrap 1 of the beakers with white and the other with black paper on the outside (tight against the glass).
2. Fill both beakers with the same amount of water and immerse a thermometer in each and read off the temperature.
3. Place both beakers at the same distance (about 50 cm) from the spot-light and switch the light on.
4. Read the temperature of each beaker after a 5 minute exposure to the light or radiated heat.

Questions:

1. Which thermometer is indicating a higher temperature?
2. Why would the two beakers show different temperatures?
3. Which are the warmer colors in general?
4. What happens to the radiated energy hitting warm colored surfaces? And cold colored surfaces?

Explanation:

The black surface absorbs the radiated heat much more than the white surface, which reflects all colors back. The black color is actually the absence of all other colors, and thus no emission of any other color occurs. The white color emits or reflects back all colors and thus does not absorb the radiated heat on the surface. In terms of molecules then, we can visualize that the molecules of the black surface vibrate much stronger than those of the white surface. The radiated energy is therefore imparted much easier to the water by the black surface than by the white one.

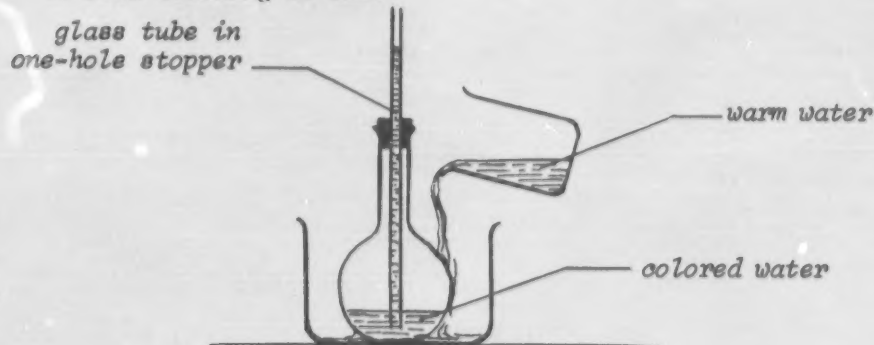
The warmer colors are red, orange, brown, and yellow in contrast to the cold colors of green, blue, purple, violet. An experiment could be set up to test the absorption of radiated heat on these colored surfaces.

HEAT

EXPANSION & CONTRACTION

7.12. THE RISING JUICES

- Materials:**
1. A flask or bottle with a narrow neck.
 2. A glass tube (30 cm) in a 1-hole stopper (for flask).
 3. One large and one small container for water.
 4. Food coloring or ink.

**Procedure:**

1. Fill the flask or bottle $\frac{3}{4}$ full with water and put a few drops of food coloring in the water.
2. Insert the one-hole stopper with the glass tube in the flask opening such that the lower end is immersed in the water.
3. Push on the stopper: the water level should rise in the tube.
4. Place the closed off flask in the larger container.
5. Pour some warm water from the smaller container over the flask: observe the water level inside the glass tube!

Questions:

1. What made the water level in the tube rise?
2. When the pouring is stopped, what made the water level in the tube go down? Where will the water level stop?
3. Was the water that was poured on the flask cold or warm?
4. How different will the rising and falling of the water level be, if we poured oil instead of water on the flask?

Explanation:

The water poured on the flask was warm, and this caused the air inside the flask to expand, pushing the water up in the tube. The higher the temperature of the poured water, the more the air inside the flask will expand and the higher the water inside the small tube is pushed up. When the pouring is discontinued, the water outside the flask is evaporating and cooling. This cooling contracts the air inside the flask and the water column descends. If we use cold water instead of warm water to pour over the flask, the air inside it will contract and bring down the water level in the tube.

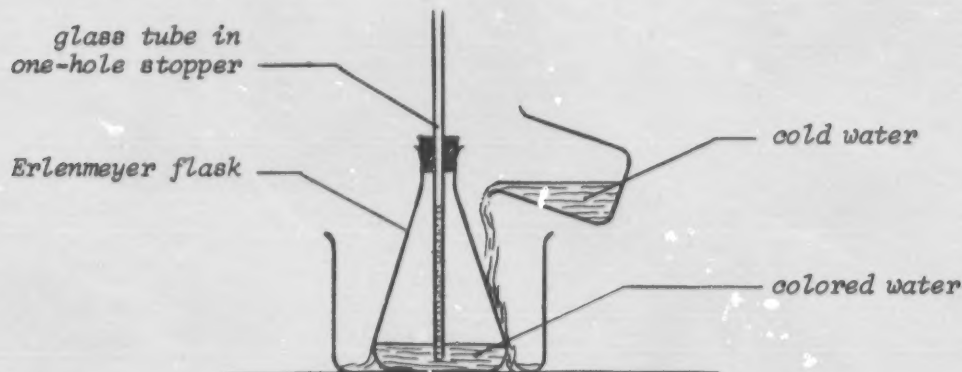
When using oil instead of water of the same temperature to pour over the flask, the rising of the water level inside the tube will be the same, but the falling will most likely be at a slower rate, because oil does not evaporate as quickly as water, and is thus not cooling as much.

HEAT

EXPANSION & CONTRACTION

7.13. WITHDRAWING JUICES

- Materials:
1. An Erlenmeyer flask (250 ml).
 2. A glass tube in a one-hole stopper (fitting in flask).
 3. A large transparent container, small beaker.
 4. Food coloring.

Procedure:

1. Fill the Erlenmeyer flask $\frac{1}{4}$ full with colored water.
2. Insert the tube with the one-hole stopper over the flask (make sure that the tube dips in the water before pushing down on the stopper--the water level in the tube should stand higher than in the flask).
3. Pour cold colorless water over the Erlenmeyer flask and have the students observe the water level in the tube.

Questions:

1. Why did the water level in the tube go down?
2. Why did the water level in the tube rise again after the pouring was discontinued?
3. Was the poured water of the same temperature as the water inside?
4. What would happen to the water level inside the tube if we would blow on the wet flask?
5. How can we make the water level in the tube rise in the first place?

Explanation:

The cold water that was poured over the Erlenmeyer flask made the air inside the flask contract, thus the pressure on the water inside the flask was lowered. This made the water column inside the tube go down. When the pouring of the cold water is discontinued, the cooling action is not completely stopped because the flask is still wet, and evaporation of the water takes place. Not until the flask is completely dry, will the water column inside the tube rise again.

By blowing on the wet flask, the cooling action--by evaporation of the water--is even more increased and a quick descent of the water results.

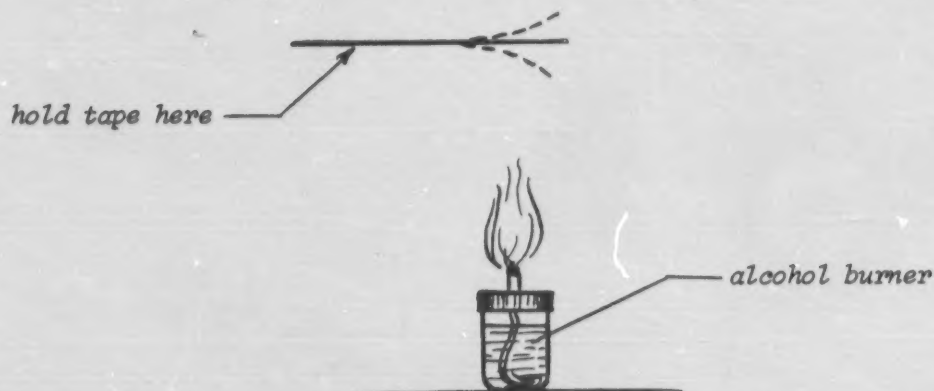
The water level in the tube can be raised by pouring warm water over the flask or simply by holding the flask in both hands. Heating the flask over a flame will have the same results.

HEAT

EXPANSION & CONTRACTION

7.14. THE CURVING TAPE

- Materials:
1. Masking tape and cello tape.
 2. An alcohol burner or other burner with colorless flame.

Procedure:

1. Take a 10 cm piece of masking tape and an equal length of cello tape.
2. Stick the two pieces of tape with their sticky side together, such that one covers the other completely (cut any excess off).
3. Hold one end of the double tape above the alcohol flame and let students observe what happens with the tape.
4. Take the tape away from the heat, straighten it out, flip it upside down (conceal this from students) and bring it back over the flame: which way does tape bend now?

Questions:

1. Why did the tape curve up or down when heated?
2. Would a regular piece of masking tape behave the same way?
3. What would two pieces of masking tape stuck together do over the flame?
4. Which of the two tapes, masking or cello, expands more when heated?

Explanation:

A regular strip (single or double) of masking tape would not curve up or down when held above the flame. The curving occurs, because the cello tape expands more than the masking tape, and because one cannot slide past the other, it makes the double tape bend towards the masking tape.

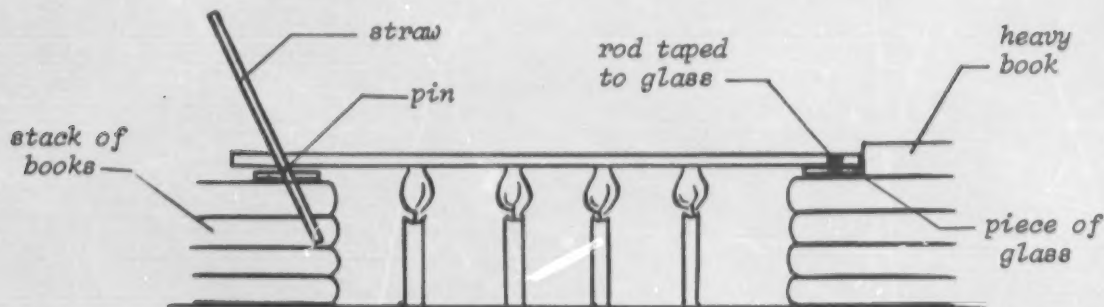
This same principle is in operation in the *bimetallic strip*, which is a strip of two different metals with different *expansion coefficients* (they expand at different rates). These bimetallic strips are used for thermal switches, thermostats, on-off lights, etc. When the temperature reaches a certain point, the strip bends enough to switch the current off; when it gets cooler, the strip bends back and switches the current on again.

HEAT

EXPANSION & CONTRACTION

7.15. THE MOVING ROD

- Materials:
1. A metal rod (about 50 cm long).
 2. Two small pieces of window glass.
 3. A straw and pin.
 4. Four or five candles or alcohol burners.

Procedure:

1. Place the metal rod on the two small pieces of window glass on two stacks of books, so that it lies horizontally (see Sketch).
2. Tape one end of the rod against the glass and place a heavy book against the end of the rod.
3. Push a pin through a straw and place the pin between the other end of the rod and the glass piece, such that it can rotate freely.
4. Place four or five candle flames or alcohol flames under the rod.
5. Let students observe the straw.

Questions:

1. How long after the candles were lit did the straw move?
2. In which direction did the straw move?
3. What was the cause for the straw to move?
4. Would the straw move the same way if the heavy book was removed before the heating of the rod?
5. What function do the glass pieces have?
6. What difference would we see in the movement of the straw, if we were to use more candles to heat the rod?
7. How would a change in the length of the rod affect the straw movement?

Explanation:

The pin is tight in the straw and thus when the rod is heated, it *expands* and turns the pin. This is magnified by the movement of the straw. The straw does not move immediately after the candles are lit, but probably a few minutes afterwards. This is because the rod needs to absorb the heat and impart this energy to its molecules.

The two glass pieces under the rod function as an insulator of heat, as well as provide a smooth surface for the pin to roll evenly. The heavy book at one end of the rod keeps this end from sliding. More candles will heat the rod to a higher temperature and thus expand it more. The longer the rod, the larger the increase in length.

HEAT

EXPANSION & CONTRACTION

7.16. THE HEAVY HEAT

- Materials:
1. A brass rod or tube with screw in one end.
 2. A razor blade, a small wooden block or molding clay.
 3. An alcohol burner.

Procedure:

1. Turn the screw into the brass rod or tube about half way.
2. Stand the razor blade vertically in the block of wood or clump of clay (this functions as the pivot for the balance).
3. Place the rod or tube on the pivot and balance it, by moving it more to the left or to the right.
4. Turn the screw out so that the rod goes off balance (towards the screw).
5. Heat the other end of the tube with the alcohol burner (see Sketch).

Questions:

1. What made the rod go off balance before the heating?
2. What happened to the rod when it was heated?
3. What made the rod tip towards the heated end?
4. What happened to the rod after the heat was taken off (after the rod tipped towards the heated end)?

Explanation:

Turning the screw out, shifted the center of gravity of the rod a little towards the screw's end, causing the rod to tip over to the right, because there is more weight at that end. When the other end of the rod is heated, it *expands* and actually gets a tiny bit longer, causing the center of gravity to shift towards the heated side. As a result the rod is coming back to a level position. When the heating is continued, the rod would expand even more, and the rod tips over to the heated end. After the rod has tipped over towards the heated end and the heating has ceased, the rod cools off, *contracts*, gets lighter on this end, and tips back to the screw end.

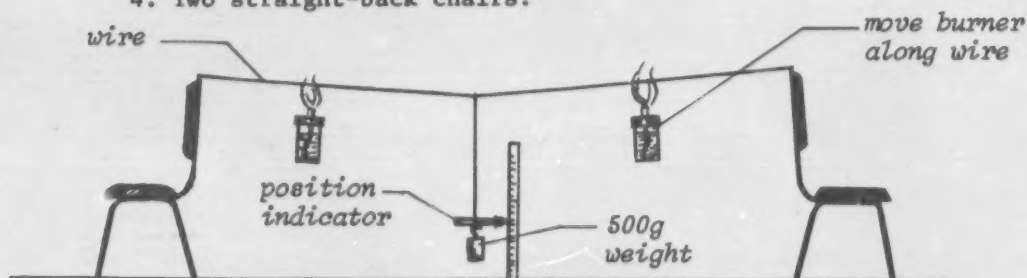
It might seem that the heating caused the mass of the heated end to increase, but this is not so. It only increased in length.

HEAT

EXPANSION & CONTRACTION

7.17. THE WEAKENING WIRE

- Materials:
1. A length of wire (copper or iron) about 3 m long.
 2. A $\frac{1}{2}$ - 1 kg weight (or rock of the same weight).
 3. Eight candles or alcohol burners, a meter stick.
 4. Two straight-back chairs.

Procedure:

1. Cut a length of about 50 cm off the wire.
2. Attach the remaining wire to two straight-back chairs and keep the wire as straight as possible by moving the chairs out.
3. Attach the 50 cm long wire to the center of the stretched wire, and hang the $\frac{1}{2}$ kg weight at the end of this wire (You might need some weight on the chairs to keep them from moving--books or students sitting).
4. Tape a small paper arrow to the weight and point it to a ruler, held vertically next to the vertical wire (taped against wall or table).
5. Heat the stretched wire with at least two alcohol burners (have a student assist you in heating one side of the wire--move the burner slowly under the wire along the whole length of it). Observe arrow!

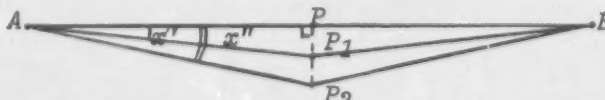
Questions:

1. Why did the weight sag down when the wire was heated?
2. How much did the weight come down?
3. Would the number of burners or candles affect the amount of sagging?
4. Would wires of different materials sag the same distance?
5. How can we calculate from the sagging of the weight how much the wire has stretched?

Explanation:

The heating of the wire by the burner flames made the wire expand, and this made the weight descend. The heating made the point of attachment of the weight move from P_1 to P_2 . By measuring the lengths AP and PP_1 , we are able to calculate the size of angle x' from $\tan x' = PP_1/AP$, and the length AP_1 from $\sin x' = PP_1/AP_1$. Similarly the angle x'' can be obtained from $\tan x'' = PP_2/AP_1$, and the length AP_2 from $\sin x'' = PP_2/AP_2$. The expansion of the wire is $AP_1 - AP_2$ times 2.

The more burners are used for the heating, the more the weight will sag. Wires of different metals will expand differently and thus result in specific amounts of sagging distances.

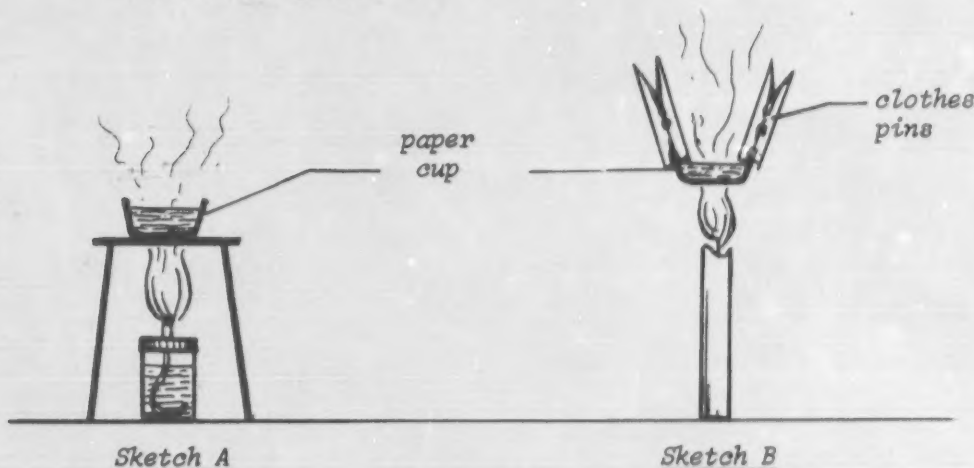


HEAT

KINDLING POINT

7.18. BOIL WATER IN A PAPER CUP

- Materials:
1. An unwaxed paper cup (cupcake baking cup suits).
 2. Alcohol burner and stand, or candle.
 3. Two cloth pins.

Procedure:

1. If paper cups are not available, a container can easily be made out of a paper card (3x5"), by folding the four corners up and clipping them with four paper clips.
2. Half fill the paper container with water and place it on the stand (see Sketch A) or use the cloth pins to hold the cup over the flame (Sketch B).
3. Light the alcohol burner or candle, and heat the water until boiling.

Questions:

1. Why doesn't the paper burn?
2. What would a waxed paper cup do if used?
3. Where does the heat of the flame go?
4. How high will the temperature of the water reach?
5. What temperature does it have to reach for the paper to catch fire?

Explanation:

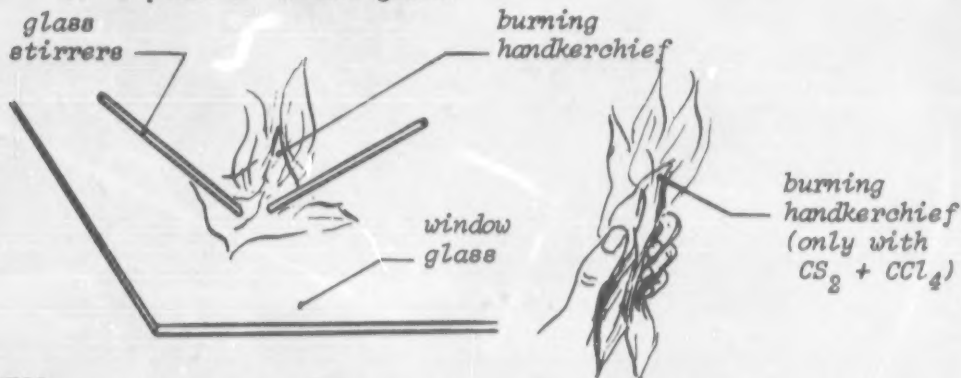
The heat released by the flame is absorbed by the water in the paper cup. It is used to increase the temperature of the water from room temperature to the boiling point, which is 100°C . At this temperature the heat is then further needed to convert the water into water vapor. The temperature of the water will stay at the boiling point (100°C) and not increase that of the cup either, until all the water is evaporated. Because the *kindling point* of paper (the temperature at which paper catches fire) is much higher than 100°C (depending on the thickness of the paper), it will not catch fire before all the water is evaporated. In other words, wet paper will not burn until it is dry. This same principle is applied when "green" wood is burned in fireplaces: it is hard to catch fire.

HEAT

KINDLING POINT

7.19 THE COOL FLAME

- Materials:**
1. Carbon disulfide (CS_2) & Carbontetrachloride (CCl_4) or ethyl alcohol & water.
 2. A medium size beaker & watch glass.
 3. Two glass stirrers.
 4. A piece of window glass.

**Procedure:**

1. Mix the two liquids $\text{CS}_2 + \text{CCl}_4$ or ethyl alcohol + water in the ratio of four to six in volume.
2. Pour a small sample of this mixture on the watch glass and test with a match for ignition. If it does not ignite, add a few ml at a time of CS_2 or alcohol to the main mixture, until a faint cool flame is sustained in the small sample.
3. You are now ready for the demonstration:
Soak a handkerchief or dollar bill in the mixture and place it on the window glass. Light it with a match and keep it moving with the two glass stirrers until the flame is out (it is most effective to do the demonstration in the dark).

QUESTIONS:

1. What made it possible to hold the burning handkerchief when using the $\text{CS}_2 + \text{CCl}_4$ mixture?
2. What is the purpose of the CCl_4 or the water?
3. Why did the handkerchief have to be kept moving?
4. Will it work if the mixture of alcohol in water or CS_2 in CCl_4 were stronger or weaker?

Explanation:

The carbon disulfide, in the presence of carbontetrachloride or the alcohol in the presence of water, gives off a flame with a rather low temperature. This low temperature is caused by the absorption of the heat by the evaporation of CCl_4 or water present. By constantly keeping the handkerchief moving, all parts of it are kept wet with the insulating CCl_4 or water. If it is not kept moving one part of it might dry out and a hot spot might develop. The more CS_2 or alcohol is used in the mixture the hotter the flame will be.

CHAPTER 8

HOW DOES MAGNETISM WORK ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

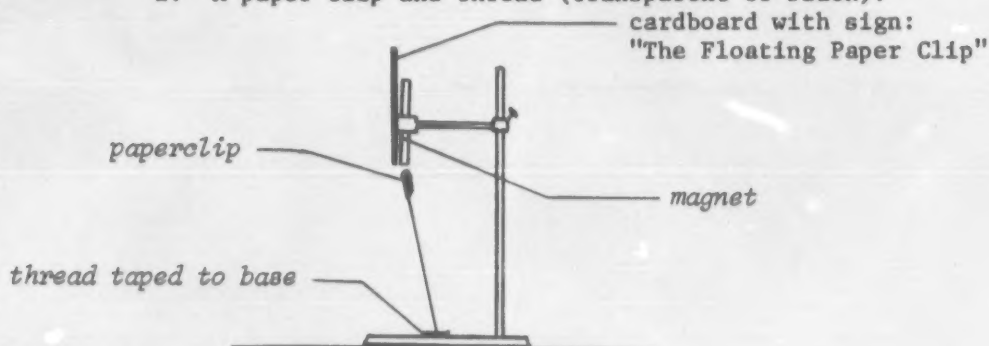
- Materials that can be magnetized or attracted to a magnet are made up of or contain either iron, nickel, or cobalt.
- Like poles repel and unlike poles attract each other.
- Around a magnet there exists a magnetic field, the magnetic lines of which run from pole to opposite pole.
- A magnet is made up of small dipole particles that are lined up in one direction.
- The North geographic pole of the earth contains South magnetism and the South geographic pole North magnetism.
- The North pole of a compass points North because man named this pole North.
- Magnetic materials can be temporarily magnetized by induction.

MAGNETISM

MAGNETIC MATERIALS

8.1. THE FLOATING PAPER CLIP

- Materials:
1. A rod magnet, stand and clamp.
 2. A paper clip and thread (transparent or black).

Procedure:

1. Clamp a rod magnet vertically and tape a cardboard sign, "THE FLOATING PAPER CLIP" in front of it. (The bottom edge should be flush with the magnet.)
2. Tie a paper clip to a thread and tape the other end of the thread to the base of the stand, such that the clip is still held up by the magnet, but leaving a gap between the two.
3. Show to students that no thread is holding the clip up by sliding thin objects through the gap (a ruler, a card, a comb, etc.).
4. Now take a pair of scissors and "cut" the magnetic lines that are holding the paper clip up.

Questions:

1. What materials could be slid through the gap without dropping the paper clip?
2. What materials will definitely "cut" the magnetic lines?
3. Which coins will go through the gap without dropping the clip?
4. Why do only some dimes(old ones) pass the gap without "cutting" the magnetic lines?
5. What were the scissors actually doing to the magnetic lines?

Explanation:

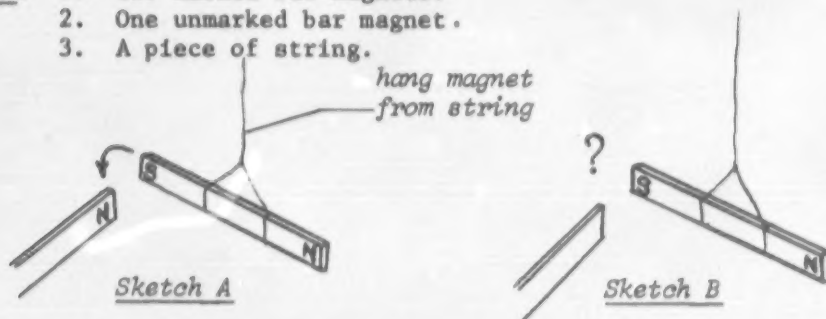
The paper clip is held up by *magnetic lines* indeed. When the magnetic lines are prevented from going through the clip, it falls. Materials that can absorb the magnetic lines from the magnet are materials which are iron, nickel or cobalt or contain any amount of it (for instance in an alloy).

Magnetism originates from within the atom. In the *magnetic materials*: iron, nickel and cobalt, the electrons around the nuclei although paired together, do not completely cancel out the magnetic fields. They could be considered as consisting of minute magnets that are randomly arranged. When these minute magnets are all lined up in one direction, the object can become a strong magnet.

MAGNETISM

RULE OF
MAGNETS8.2. WHICH POLE IS ATTRACTED?

- Materials:
1. Two marked bar magnets.
 2. One unmarked bar magnet.
 3. A piece of string.

Procedure:

1. Tie a string to a marked bar magnet and let the magnet hang horizontally from the left hand (or from a stand).
2. Approach this free rotating magnet with another marked bar magnet in your right hand. Let students observe what the north and south end of the hanging magnet will do when another north or south end approaches it.
3. Now replace the marked bar magnet in your right hand with an unmarked bar magnet, and ask students: "Which pole will swing towards this approaching magnet?"
4. Wait for students' reactions (some anticipated answers: We don't know until you tell us what pole is coming near the hanging magnet).
5. Say: "If I tell you what pole I have in my right hand, can you tell me which one will be attracted to it?"

Questions:

1. Can you make a rule that all magnets will follow?
2. What would the hanging magnet do when approached with a regular steel bar?
3. What can you tell about the approaching bar if the N as well as the S pole swings towards it?

Explanation:

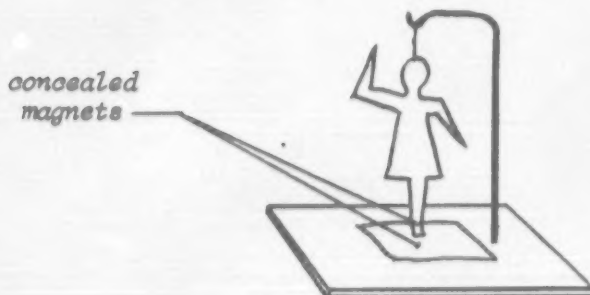
The main purpose of this demonstration is to elicit the rule of magnetism-- "Like poles repel and unlike poles attract"--from the students themselves. By showing them the phenomenon sketch several times, with different poles approaching the hanging magnet, they should be able to form and understand the concept themselves.

By approaching the hanging magnet with an identical steel bar, which is not magnetized, both poles will be swinging towards it. This happens because the molecules in the non-magnetized bar are still randomly arranged and a north as well as a south pole of a magnet can attract the steel bar. A nail will have the same properties.

MAGNETISM

ATTRACTION &
REPULSION8.3. THE MAGIC DANCER

- Materials:
1. Two small disc magnets.
 2. A wooden stand, tape.

Procedure:

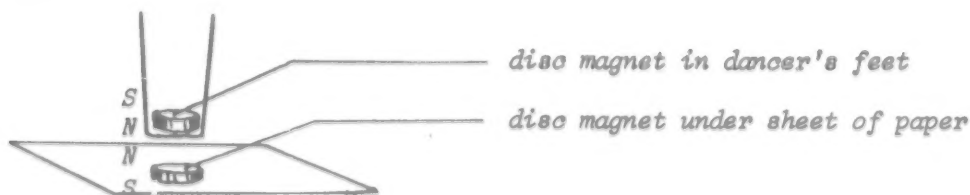
1. Construct a stand of wire in a wooden base and cut out a cardboard dancer figure.
2. Hang the dancer on the stand with a thread.
3. Tape a disc magnet directly under the figurine and conceal another disc magnet at the end of the leg of the figurine.
4. Move the dancer a little and observe.

Questions:

1. Why does the figurine keep on moving?
2. How do the magnet poles have to be arranged?
3. Why does the base have to be made out of wood?

Explanation:

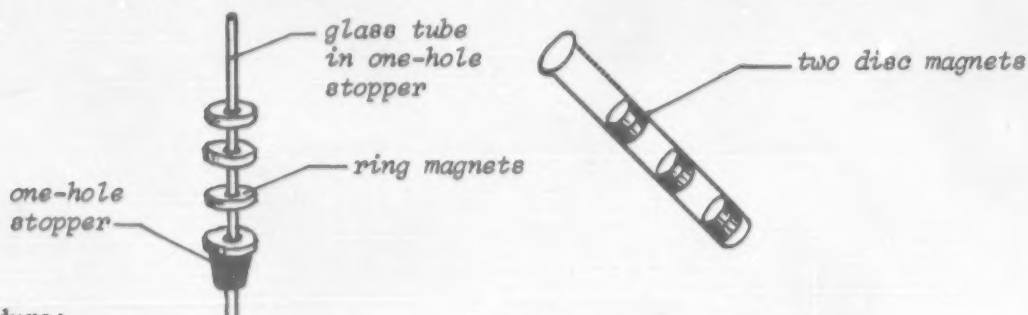
The two concealed disc magnets are placed facing each other with like poles, so that they repel each other. This way the figurine keeps on bouncing away from the point vertically under it, causing it to move and twirl for quite an extended time. If the base of the stand were made out of iron or any other magnetic material, the magnet concealed in the base would lose much of its magnetism and the upper magnet would be attracted to any part of the base and would stop to move.



MAGNETISM

ATTRACTION &
REPULSION8.4. THE FLOATING DISCS

- Materials:
1. Six or eight small disc magnets (or ring magnets).
 2. A test tube (for the discs) or a glass tube in a one-hole stopper (for the rings).

Procedure:

1. Stick the six or eight disc magnets together two by two.
2. Slide the first pair in the bottom of the test tube.
3. Slide the second pair in the tube, such that they repel the first pair. (If they are attracted to the first pair, take all four out, turn the two upper discs upside down and slide them back in the tube).
4. Do the same with the next two pairs of disc magnets.
5. In case ring magnets are used: slide them around the glass tube, such that they repel each other (see Sketch B).

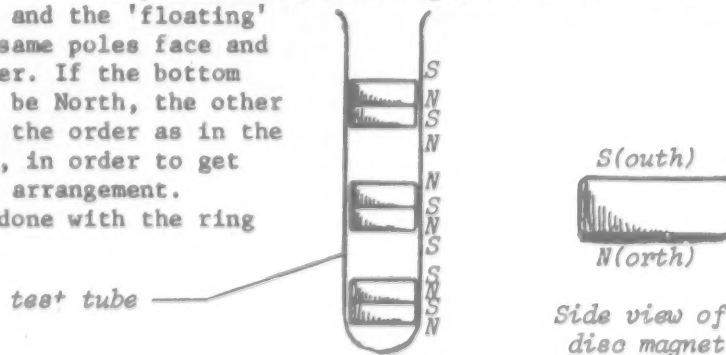
Questions:

1. Why do the pairs of discs stick together?
2. Where would the poles of the disc magnets be located?
3. Assign a letter N or S for each of the poles.
4. How could we get the discs out of the test tube without turning the tube upside down?

Explanation:

The pairs of discs have unlike poles facing each other and therefore they attract each other. The poles of the disc magnets are located at its two circular flats, and the 'floating' occurs because the same poles face and thus repel each other. If the bottom pole is assigned to be North, the other poles have to be in the order as in the sketch on the right, in order to get the 'floating' pair arrangement.

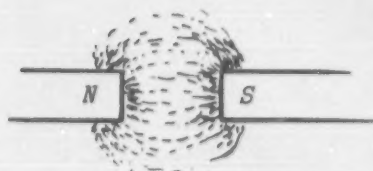
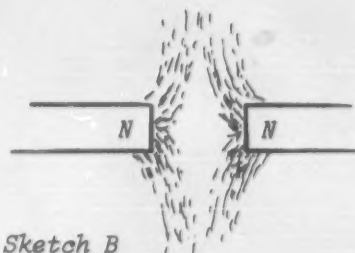
The same can be done with the ring magnets.



MAGNETISM

MAGNETIC LINES
OF FORCE8.5. SEEING MAGNETIC LINES

- Materials:
1. Two rod or bar magnets (and other shape magnets).
 2. A transparency or glass sheet
 3. Iron filings.

Sketch ASketch BProcedure:

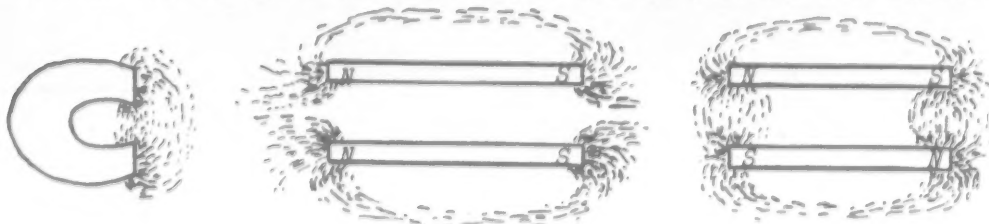
1. Place two bar magnets with the unlike poles about 4-5 cm apart on an overhead projector (if not available: let students gather around).
2. Cover the magnets with a blank transparency and sprinkle some iron filings close to the poles especially. (When an overhead projector is not available, a sheet of window glass or white paper will do).
3. After sprinkling the iron filings, tap lightly on the transparency (glass or paper).
4. Do the same (step 1 to 3) with the two like poles together or facing each other (Sketch B)

Questions:

1. What do the two different patterns of lines indicate?
2. How would the magnetic-line-pattern of a horseshoe magnet look?
3. How would the pattern of lines look, if the bar magnets were placed parallel to each other, with like poles next to each other?
With unlike poles next to each other?
4. How would the magnetic line pattern of one bar magnet look?

Explanation:

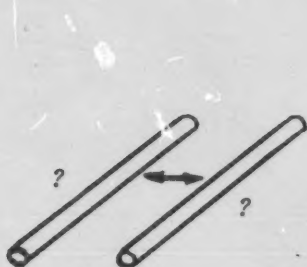
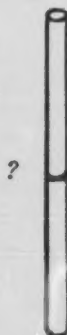
Any thin sheet of material that is not magnetic (not iron, nickel or cobalt) can be used to show the magnetic lines with iron filings. The use of the transparency and overhead projector has the advantage, that it can be clearly shown to the whole class at one time. Students should gather around a little closer when it is not projected. These are the patterns that will show up for a horseshoe magnet and the parallel bar magnets:



MAGNETISM

MAGNETIC LINES
OF FORCE8.6. WHICH ONE IS THE MAGNET?

- Materials:
1. A strong bar magnet.
 2. An identical steel bar (not magnetized).

Sketch ASketch BSketch CProcedure:

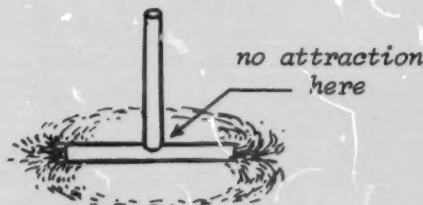
1. Show the students the two identical bars and say: "One of these bars is a magnet. How can we tell which one it is, without using any other materials?"
2. Carry out whatever the students want you to do (let one bar roll on the table attracted to the other bar (Sketch A) or put pole against pole (Sketch B), might be some suggestions.
3. If students do not suggest the set-up of Sketch C, give them a clue to think about the magnetic lines flowing around a bar magnet (Event 8.5), and ask: "Where would the magnet be weakest in attraction force?"
4. Then show and demonstrate configuration C.

Questions:

1. Can we tell which one is the magnet with set-up A or B?
2. If the vertical bar attracts the horizontal bar (Sketch C), which one is the magnet?
3. Why would the end of the steel bar (the non-magnet) not attract the middle of the bar magnet?
4. How do the magnetic lines of force flow around the bar magnet?

Explanation:

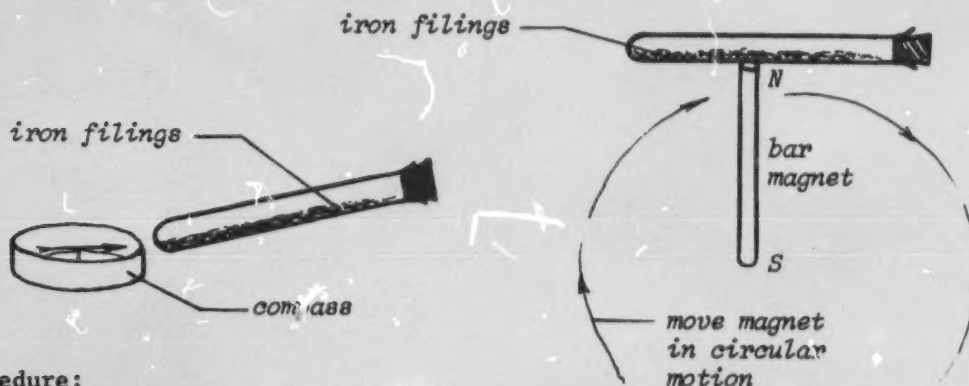
Whether the bars are placed against each other as in Sketch A or B, there is no way to tell which of the two bars is the magnet, because there is no repulsion, as one of the bars is a regular non-magnetized steel bar. The only way to tell which one is which, is by holding the bars as in Sketch C, as the magnetic field in the center of the bar magnet is weakest. You might say that the two poles of the magnet neutralize each other in the center of the bar.



MAGNETISM

MAGNETIC MATERIALS
MAKE-UP OF A MAGNET8.7. THE TEST TUBE MAGNET

- Materials:
1. A test tube and fitting cork.
 2. A strong magnet and iron filings.
 3. A small compass (or needle compass: Event 8.9).

Procedure:

1. Place some iron filings in the test tube, cork it and shake the filings while holding the tube horizontally.
2. Bring the end of the tube close to the compass and show that the compass needle is not or very little attracted; also let students note that the same needle end is attracted to the test tube, no matter which end of it is approaching the needle (compass).
3. Now take the strong bar magnet and magnetize the iron filings in the test tube by stroking the bottom side of the horizontally held tube with one pole of the magnet in a circular motion (see Sketch).
4. After stroking the tube with the magnet for about 5-6 times, show that the test tube acts as a regular bar magnet by approaching the compass with the two ends of the tube.

Questions:

1. Why is the compass needle attracted to the iron filings before the tube was magnetized?
2. Why does the stroking of the test tube have to be done with a circular motion?
3. How can we know whether the iron filings in the test tube are magnetized or whether they are not?
4. How would the compass needle behave, if a regular bar magnet approached the compass?
5. What could we use if we did not have a compass?

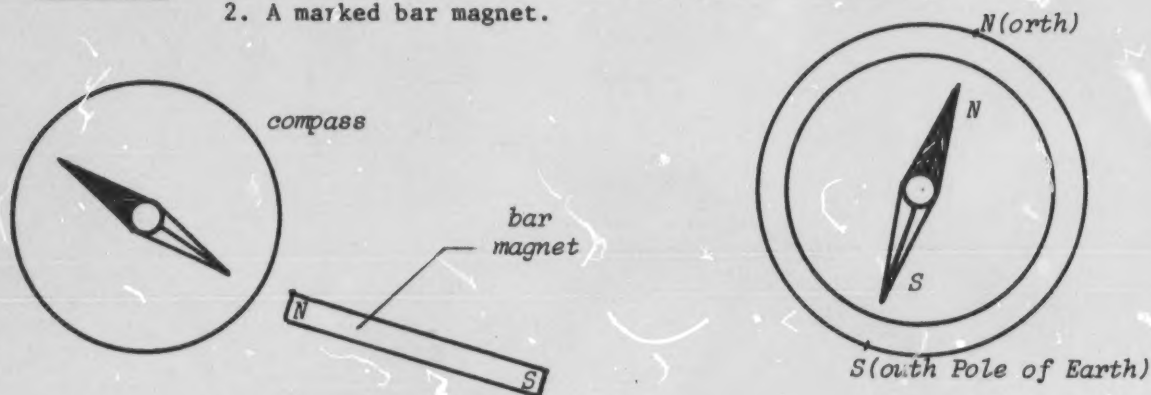
Explanation:

A bar magnet is made up of very tiny particles that have very weak dipoles or North and South magnetism, just like the iron filings in the tube. They are scattered randomly in the bar. When these particles are lined up by stroking with a strong magnet, the bar becomes a magnet. This is demonstrated by the iron filings in the test tube. When the tube is shaken after it is magnetized, the particles are distributed randomly again, and no magnetism is left in the tube.

MAGNETISM

EARTH MAGNETISM
MAGNETIC RULE8.8. MAGNETIC CONFUSION

- Materials:
1. A small compass (one for each pair of students).
 2. A marked bar magnet.

Procedure:

1. Distribute the compasses and ask: "which end of the needle is the North end, and which one is the South end?"
2. "How can we find out?" Come around with the marked bar magnet and approach each compass with the North pole of the bar magnet.
3. Now that the students already know which end of the compass needle is North and which end is South, ask: "Which end of the compass points in the North direction?"
4. "Is North attracted by North? Is this not against our magnetic rule?"

Questions:

1. How did we find out which end of the compass was North?
2. If we did not have the marked bar magnet, how could we find this out?
3. If the marked bar magnet was hung on a string, which pole would point to the North pole of the earth?
4. If there were no marked bar magnets to find in the whole world (which was the case before magnetism was discovered), how would we label the first bar magnet?

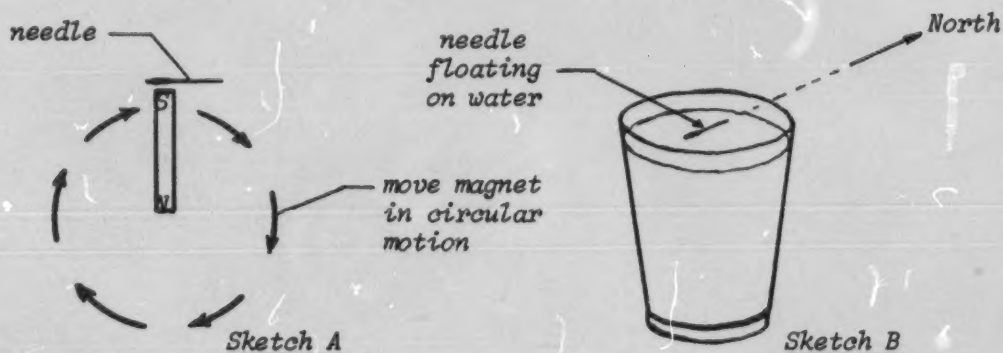
Explanation:

This activity poses the student with a real discrepancy, especially after learning the magnetic rule: *unlike poles attract and like poles repel*. The fact that the North end of the compass needle points to the North pole of the earth, is because this compass needle end is a north-seeking one and thus named 'North'. The situation is then that, either the earth's North pole contains South magnetism, or that all North labeled bar magnets are actually the South pole. The most simple fact to remember for students is: that the North end of the compass needle is named North, because it is North-seeking.

All bar magnets, when hung from a string, will line up in the North-South direction. The North pole of the bar will point to the North pole of the earth, because it is North-seeking.

8.9. MAKE A NEEDLE COMPASS

- Materials:
1. A fine sewing needle, a piece of candle.
 2. A strong magnet, and a glass or cup.

Procedure:

1. Take the needle between the fingers of one hand, and with the other hand rub the pole of the magnet against the needle in *only one direction*. After each stroke, move the magnet away from the needle and approach the needle from the 'eye'-side (Sketch A). Do this about 10 times.
2. Hold the needle between thumb and forefinger horizontally and approach the water surface as close as possible without touching it, then drop the needle. (When needle sinks, rub it against the candle before floating it, so that it would repel the water).
3. Once the needle is afloat, it will point only in one direction. Test this by approaching the cup with a magnet and removing it.

Questions:

1. When stroking the needle with the magnet, why can't we rub the needle back and forth against the magnet?
2. When rubbing the needle from eye to point with the south pole of the magnet, which end of the needle will point north?
3. Which end of a compass needle will point north?

Explanation:

The rubbing of the needle with one pole of a magnet should be done only with one-direction strokes, because the purpose of the rubbing is to align the tiny particles of the needle in only one direction. When the rubbing is done with a back and forth motion, this alignment is not achieved as well. When the south end of the magnet is used to rub the needle from eye to point, the point will be the north pole of the needle, and thus this will point north. This is not because 'north' is attracted by 'north', but because the earth's north pole contains 'south' magnetism.

Other ways to suspend the magnetic needle are: hanging it on a thread in a jar from a glass rod or wooden stick, which is resting on the opening of the jar; floating it on a wide flat cork disc on the water surface.

MAGNETISM

MAGNETIC INDUCTION

8.10. THE TEMPORARY MAGNET

- Materials:
1. A strong bar magnet.
 2. A long iron nail.
 3. Paperclips or thumbtacks or small nails.

Procedure:

1. Place some paperclips, thumbtacks or small nails on a sheet of paper.
2. Touch the point of an iron nail to the heap of paperclips and see if it will pick up any of the objects (it should not pick up any).
3. Hold one pole of the strong magnet against the nail head and touch the other end to the small iron objects again (some will be picked up now: see Sketch above).
4. Remove the magnet now from the nail (the small objects will drop).
5. Repeat point 2, 3, and 4 to show the temporary nature of the nail as a magnet (induction).

Questions:

1. What made the nail become magnetic?
2. Could a copper or aluminum nail do the same thing?
3. If the north pole of the magnet were touching the nail, what pole would the nail point be?
4. What is the process of temporary magnetization called?
5. What other materials can be temporarily magnetized?

Explanation:

The magnetic field surrounding the strong magnet can temporarily magnetize objects made of iron, nickel or cobalt. When this happens, it is said that the object is magnetized by induction and that the object is a temporary magnet. When the north pole of the magnet touches the nail head, this becomes the south pole and the nail point becomes the north pole.

The particles (dipoles) of the nail are lined up in one direction and the whole nail becomes temporarily a magnet. As soon as the permanent magnet is taken away, the particles revert back to their random distribution and the nail's magnetism disappears.

CHAPTER 9

WHAT IS STATIC ELECTRICITY ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

- Rubbing certain objects will result in the removal of electrons and a build up of positive or negative charges.
- Certain uncharged objects are attracted by charged objects.
- There are two kinds of static charges: positive and negative.
- Certain objects may be charged by induction.
- Capacitors are collectors of small static charges.

STATIC ELECTRICITY

ATTRACTION OF
UNCHARGED OBJECTS9.1. THE IMAGINARY SHELF

- Materials:
1. Three or four balloons.
 2. A clean blackboard or dry wall space.

Procedure:

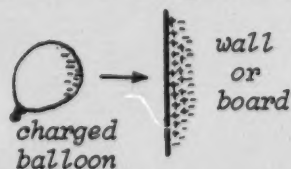
1. Blow three or four balloons up. Tell students that you constructed an imaginary shelf on the blackboard.
2. Rub the balloons carefully (do not press too hard) against your sleeve or shirt, as if cleaning the dust off the balloon, then stick it to the blackboard in a horizontal row.
3. When students catch on about the rubbing of the balloons, have them try to make a second lower 'shelf' with other balloons rubbed against their hair or shirt.

Questions:

1. How did the balloons get to stick to the board?
2. What did the rubbing do to the balloon?
3. Try rubbing the balloon against wool, silk, cotton, or hair. Do you find any difference in the static charge built up?
4. Why do you think the balloons will stick better to the wall on a very cold winter day than on a rainy day?
5. What are other materials that can be charged by rubbing?
6. Can the balloons stick to the walls indefinitely?

Explanation:

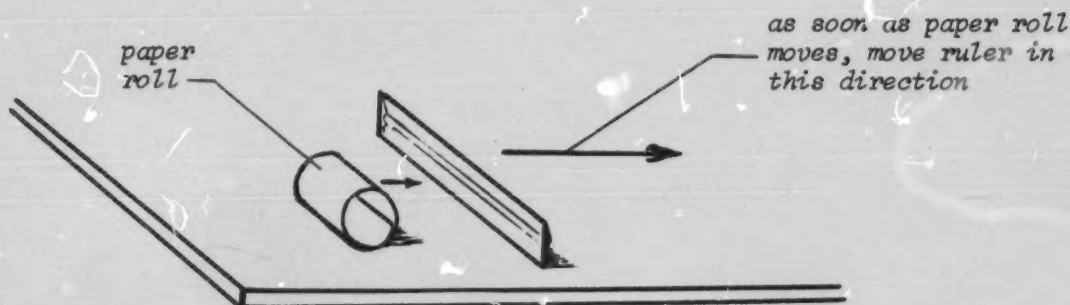
By rubbing the balloons, the material that was rubbed against it lost some electrons, and thus the balloon obtained an excess of electrons, which means that it has a negative charge. The easier the material used to rub the balloon is able to lose electrons, the easier the balloon gets charged. Wool, cotton or hair are the most common materials to charge the balloons. When the negatively charged balloon approaches the board, the negative charges are repelled and thus a positive charge is induced at the spot where the balloon touches the board. Because of this, the balloon sticks to the surface of the board. Over a longer period of time, electrons will transfer from the balloon to the board and so the balloon gets neutralized and falls to the floor. The losing of the excess charge occurs easier in damp weather, and this is the reason why it is easier to build up charges in winter.



STATIC ELECTRICITY

ATTRACTION OF
UNCHARGED OBJECTS9.2. THE MAGNETIC RULER

- Materials:
1. A regular plastic ruler and handkerchief.
 2. A short thin strip of paper.

Procedure:

1. Make a small roll (about 2 cm diameter) from the strip of paper, so that it can roll over a smooth surface.
2. Take the ruler in one hand and the handkerchief in the other, and rub the ruler with it vigorously.
3. Approach the paper roll slowly until it moves, then move it away from the roll (try to keep pace with the rolling of the paper).

Questions:

1. What initiated the attraction of the paper to the ruler?
2. Is the ruler or the paper magnetic?
3. Can static electricity be considered a force?
4. Where did the initial energy originate?

Explanation:

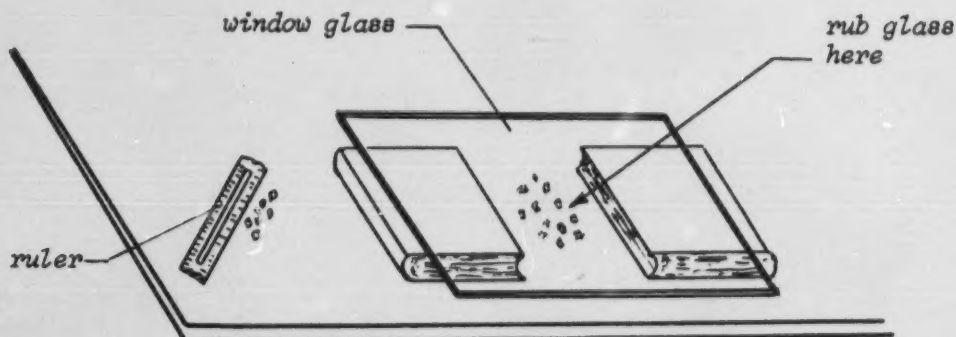
The rubbing of the ruler was muscle energy, or mechanical energy, turned into static electricity. The ruler is charged with an excess of negative charges and approaching the uncharged roll of paper, the latter gets attracted to the ruler. Almost anything can be rubbed and charged; some materials are easier to charge than others. The paper roll is attracted to the charged ruler, because the opposite charge is being induced in the paper, and an attraction occurs. Any attraction resulting in a movement of an object shows that a force is involved, thus *electrostatic energy is a force*. This can easily be observed, where the paper cylinder rolls from one end of the table to the other, as a result of the attraction of the charged ruler.

Static electricity charges with their attraction and repulsion properties are often confused with magnetic properties. These are two separate and distinct entities. The first is obtained by the removal or addition of electrons by mechanical means (rubbing), and the latter by sorting or arranging the randomly distributed magnetic fields of the tiny particles (dipoles) of the material in one direction.

STATIC ELECTRICITY

ATTRACTION OF
UNCHARGED OBJECTS9.3. THE PAPER JUMPING JACKS

- Materials:
1. A piece of window glass, a wool rag.
 2. A plastic ruler and a handkerchief.

Procedure:

1. Place two books of the same thickness about 10 cm apart.
2. Put some small paper snippers between the books and cover them with the piece of window glass.
3. Rub the top of the glass with the wool rag (do not push too hard) and let students observe the paper snippers.
4. When window glass is not available, use the plastic ruler and rub it with a handkerchief. Approach the paper snippers and observe them jump up to the ruler and fall down again.

Questions:

1. What did the rubbing do to the glass or plastic?
2. Why did the paper snippers jump up and down?
3. What other materials can be used instead of the paper snippers?
4. What other materials can replace the glass or the ruler?

Explanation:

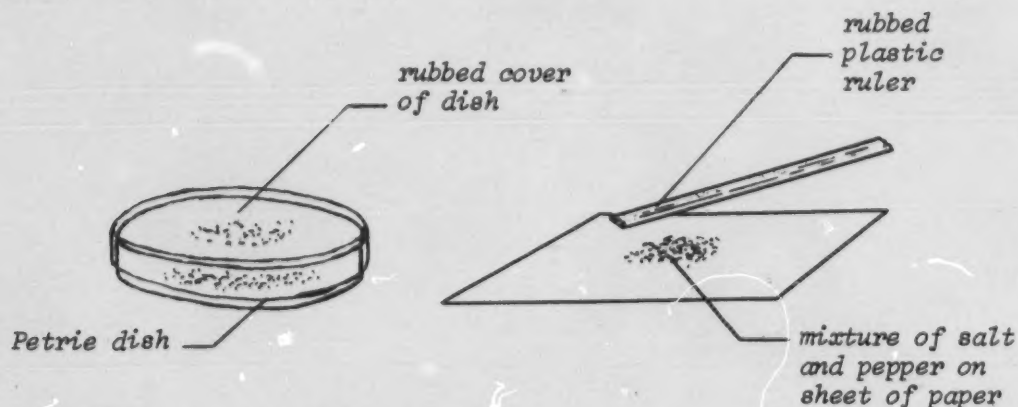
By rubbing the window glass or plastic ruler, negative charges are built up on the glass and ruler. The paper snippers are attracted to this charge, because the opposite charge is induced in them. At the moment that they touch the glass or ruler, the electrons can migrate to the paper; this gives it the same charge and thus they are suddenly repelled. As soon as they are back on the table, the paper snippers lose this excess charge to the table top, leaving them neutral, and the process can start all over again. This jumping back and forth from table to glass sheet can occur in very quick succession or it may take a longer time.

Other materials to replace the paper snippers would be: confetti, pepper, cork powder, fine dry saw dust, etc. Instead of the glass sheet or the ruler, we may also use: a blown up balloon, a transparency (for an overhead projector), a plastic comb, or any other plastic object, etc.

STATIC ELECTRICITY

ATTRACTION OF
UNCHARGED OBJECTS9.4. SEPARATE THE PEPPER FROM THE SALT

- Materials:**
1. Table salt and ground pepper.
 2. A plastic Petrie dish, flannel or wool cloth.
 3. A plastic ruler, flannel or wool cloth.

**Procedure:**

1. Place some salt and pepper in the plastic Petrie dish and put the cover on. Shake the two granulated substances and mix them. Ask the students: "How can I separate the pepper from the salt without using water?"
2. Rub the cover of the dish with the flannel or wool cloth (or your dry palm of the hand) and turn the dish upside down for a short moment (the pepper should stick to the cover).
3. The pepper can also be separated by placing the mixture on a sheet of paper and holding a plastic ruler that was rubbed with the wool cloth, over the mixture (the pepper should fly up and stick to the ruler).

Questions:

1. What made the pepper stick to the dish cover or ruler?
2. What did the rubbing do to the dish cover or ruler?
3. Why did only the pepper stick to the rubbed surfaces?
4. What would be another way to separate the two substances?

Explanation:

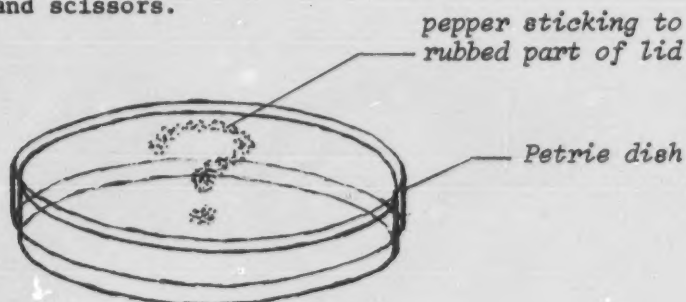
By rubbing the plastic surfaces with the wool cloth, these surfaces were charged with static electricity (from the excess electrons left on the plastic by the wool). The uncharged pepper particles got attracted to these surfaces, as opposite charges were induced in them, whereas no charges are induced in the salt particles.

Another way of separating the two substances is to sprinkle the grains of the mixture over the water surface in a container. The salt would sink and the pepper particles would float on the water surface, which could be scooped out. The salt will recrystallize after the water evaporates.

STATIC ELECTRICITY

ATTRACTION OF
UNCHARGED OBJECTS9.5. THE PEPPER REPRODUCTION

- Materials:
1. A plastic Petrie dish and lid (for each pair of students).
 2. A piece of wool cloth (for each pair of students).
 3. A pepper shaker.
 4. Paper and scissors.

Procedure:

1. Distribute the Petrie dishes and the wool cloths to the students.
2. Have them place a pinch of pepper in each of the Petrie dishes, put the cover on them and scatter the pepper over the bottom.
3. Let the students take a piece of paper the size of the plastic dish and cut out a stencil from it (a letter or any shape).
4. Have them, while holding the paper stencil against the top of the dish, rub the open area with the wool cloth vigorously.
5. Now have them remove the stencil and invert the dish and then turn it right side up. Ask: "What do you see sticking to the cover?"

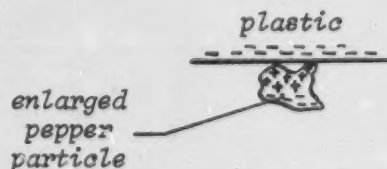
Questions:

1. Why did the pepper stick only to the rubbed parts of the lid?
2. What charge did the pepper have?
3. Why did the pepper stay attracted to the plastic?
4. What are the industrial applications of this principle?

Explanation:

The paper stencil allowed rubbing of the plastic lid at certain confined areas. Only these areas were charged and thus the pepper, which was uncharged, was attracted to the charged areas. The pepper particles stayed attracted, because they are electrical insulators and also because they are irregularly shaped. It is thus not so easy for the electrical charges to transfer themselves from the plastic to the pepper particles.

Rubbing the plastic with the wool created negative static electricity, which induced positive charges on the upper side of the pepper particles. (see Sketch on the right).

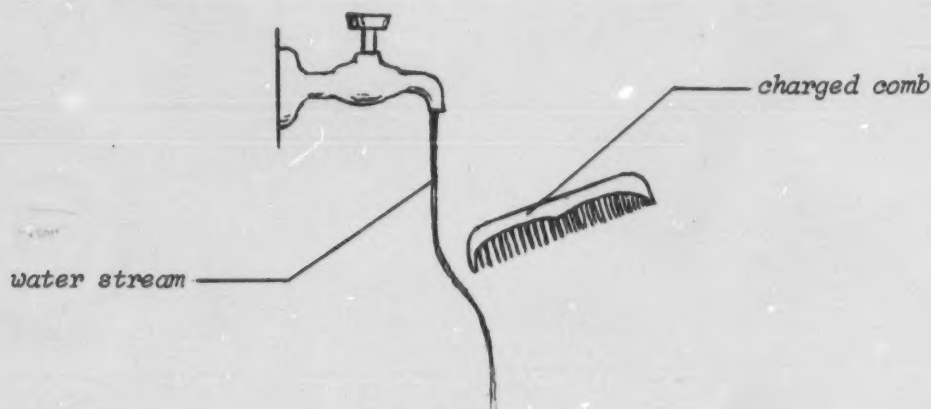


Industrial applications of this principle can be found in photocopying, removing of dust from exhaust fumes, industrial painting (paint particles negatively charged and target strongly positive charged.)

STATIC ELECTRICITY

ATTRACTION OF
UNCHARGED OBJECTS9.6. BEND THE WATER STREAM

- Materials:
1. A large plastic comb.
 2. A wool, flannel, or felt cloth.
 3. A small water stream (from tap or small hole in a can).

Procedure:

1. Open the tap and adjust it such that a small stream of water runs out of the tap (or hold a leaking can with water above a bucket).
2. Rub the comb with a wool, flannel or felt cloth and hold the back of the comb about 2 cm from the stream (move the comb slowly closer to the stream if it is not attracted to it).
3. Make sure that all students observe the stream being bent, as a side view. In order to do this, approach the stream from different sides.

Questions:

1. Why did the water stream bend towards the comb?
2. Was it a magnetic force that attracted the water?
3. What other materials can we use instead of the comb?
4. Would a larger stream of water also be bent?
5. What would happen if the charged comb got wet?

Explanation:

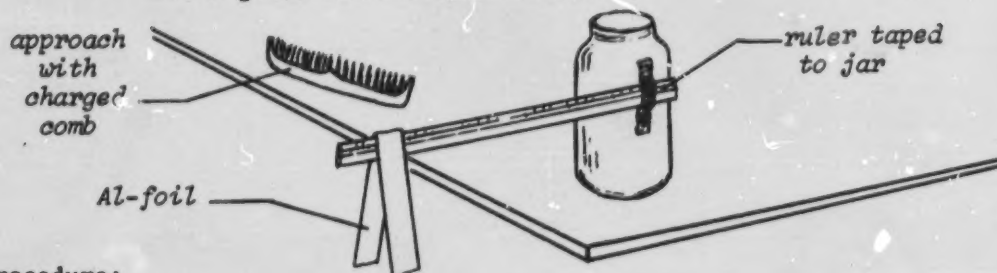
The charged comb induces an opposite charge in the water stream and this latter therefore gets attracted by the comb. The mass has to be small enough for the electrostatic charge to move the mass. The static attraction force is relatively small and thus larger masses are not moved. This is why the water stream has to be small so that it can be attracted by the charged comb. A larger stream needs a much larger static charge to bend.

It is suggested not to get the comb wet. The water would take away all charges and it would be very hard to get the comb recharged with static electricity. Other materials that can be used instead of the comb are: a balloon, hard rubber, a ruler, a glass rod rubbed by silk, etc.

STATIC ELECTRICITY

ATTRACTION &
REPULSION9.7. THE ALUMINUM FOIL ELECTROSCOPE

- Materials:**
1. A strip of aluminum foil, masking tape.
 2. A plastic ruler (30 cm), an empty jar.
 3. A plastic comb and wool cloth.
 4. A glass rod and silk cloth.

**Procedure:**

1. Tape the ruler horizontally to the side of the jar like in the Sketch.
2. Fold a strip of aluminum foil double (about 2 cm wide and 20 cm long) and let it hang over the end of the ruler.
3. Make sure that the foil strips are hanging very close to each other (this can be done by folding or rubbing/smoothing the strips).
4. Rub the comb with a wool cloth and approach the top of the strips with it (strip ends open), and withdraw comb (strip ends close).
5. Rub the comb again with a wool cloth, approach the top of the strips and touch it (strip end will stay open).
6. Rub the glass rod with a silk cloth and approach the top of the charged electroscope with the glass rod (strip ends close), then withdraw the charged rod (strip ends open again).

Questions:

1. What happens to the charges in the Al-foil when approached with a positive charge?
2. Why did the Al-strips stay open when touched with the charged comb?
3. What happened to the charges of the foil when approached by the charged glass rod?

Explanation:

The sequence of flow of charges in the aluminum foil is best explained in the following sketches: I) Uncharged strips. II) Foil strips induced. III) and IV) Touching and removing the charged comb leaves foil strips

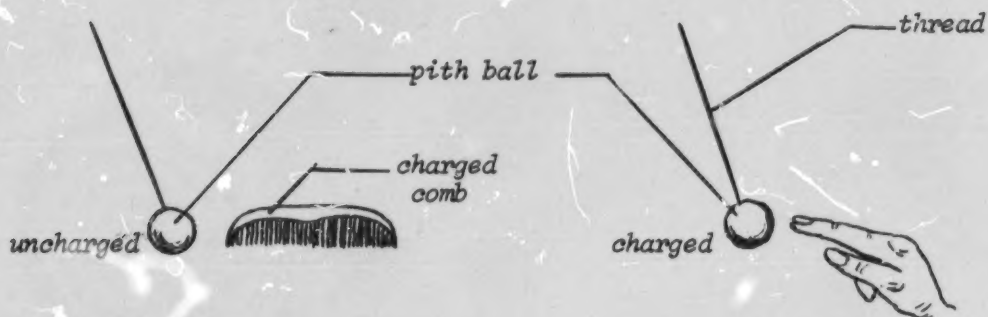


charged. V) Approaching the positively charged foils with the glass rod neutralizes them. VI) Removing the glass rod makes the foil strips repel each other again, because of the same positive charge returning to the foil tips.

STATIC ELECTRICITY

ATTRACTION &
REPULSION9.8. THE CONFUSED PITHBALL

- Materials:
1. Pithball and thread (the pithball can be made out of a styrofoam ball covered with pencil lead).
 2. A plastic comb and a wool cloth.

Procedure:

1. Suspend the pithball from a thread attached to a stand.
2. Rub the comb with the wool cloth and ask the students: "What will the pithball do when it is approached by the comb?"
3. Bring the comb near the suspended pithball and show that indeed the ball is attracted towards it.
4. Show this attraction several times without touching the ball. Now come a little closer to the ball with the comb and let them touch each other.
5. Now approach the charged ball with your finger.

Questions:

1. What caused the ball to be attracted by the comb?
2. If the comb was negatively charged, what charges were induced in the pithball?
3. What made the ball suddenly repel the charged comb?
4. What charge does the repelling ball have?
5. Why is the charged ball attracted by the finger?
6. What happens after the charged ball is touched by the finger?

Explanation:

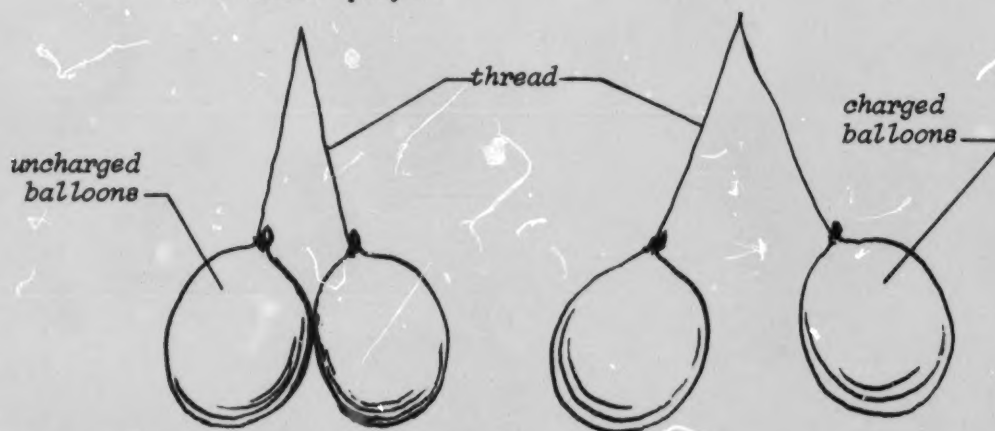
1. When the comb is approaching the ball, there is an attraction, because a charged object attracts an uncharged object (the pithball) (Sketch 1).
2. As soon as the comb touches the ball, charges of the comb are transferred to the ball (Sketch 2).
3. The ball is now repelled because like charges repel (Sketch 3).
4. In bringing the finger close to the charged ball, it is attracted to the finger (uncharged object) (Sketch 4).
5. As soon as the ball touches the finger, the charges are neutralized and there is no attraction nor repulsion by the finger (Sketch 5).



STATIC ELECTRICITY

ATTRACTION &
REPULSION9.9. THE BALLOON ELECTROSCOPE

- Materials:
1. Two identically shaped balloons.
 2. A wool cloth and thread.
 3. A water sprayer.

Procedure:

1. Blow two identical balloons up to about the same size and tie a thread to each of them.
2. Hold the two threads together and show that the balloons will hang against each other (without any rubbing beforehand) (Sketch A).
3. Now let a student hold the threads, rub the balloons with the wool cloth, and let them hang back (balloons will not touch: Sketch B).
4. Spray a mist of water against the balloons (they will fall back against each other (like in Sketch A)).

Questions:

1. Why did the balloons repel each other after the rubbing?
2. Why did the balloons fall back against each other after spraying?
3. How else could we let the balloons fall back against each other?
4. What needs to be done to have the balloons fall back?
5. During which time of year would it be best to do experiments on static electricity?
6. What is damp weather doing to the electric charges?

Explanation:

After rubbing the balloons, they were charged with the same charge and thus they repelled each other. By spraying water droplets in their vicinity, the water droplets carry the charges away from the balloons, rendering them neutral, with the result that they fall back against each other.

Another way to neutralize the charges on the balloons is to touch them with a damp or moist hand.

STATIC ELECTRICITY

INDUCTION

9.10. THE INDUCED CHARGE

- Materials:**
1. A pithball and thread.
 2. A plastic rod & fur, or glass rod & silk.

**Procedure:**

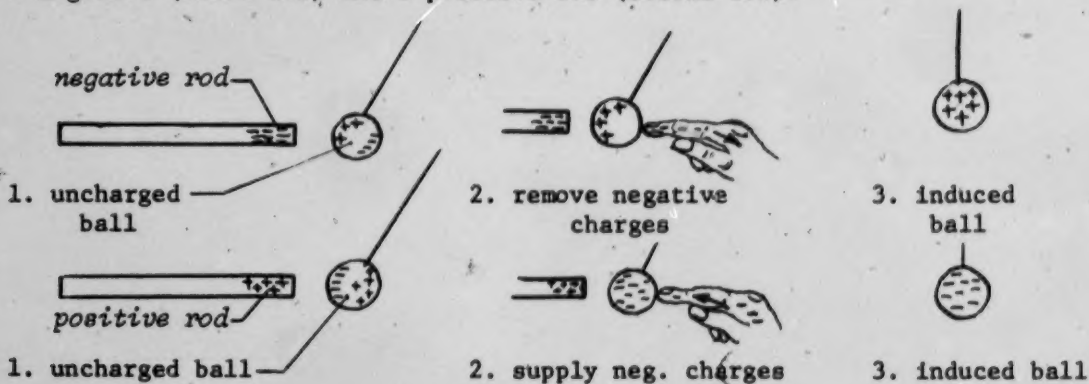
1. Suspend the pithball from a thread.
2. Rub the plastic rod with the fur (or the glass with the silk) to produce negative charges.
3. Approach the pithball with the charged rod (do not touch) with one hand, while touching the other side of the ball with the finger of the other hand (see Sketch above).
4. Remove the finger and then remove the charged rod.
5. Now approach the pithball with a finger: what happens?

Questions:

1. What was the pithball doing when approached by the charged rod?
2. What charges would be induced in the ball by the charged rod?
3. What did the touching with the finger do to the charges on the ball?
4. Why does the finger have to be removed first before the rod?
5. What final charge does the ball have?
6. What final induced charge would the ball have, if it was approached with a positively charged rod?

Explanation:

Here follow three steps each for the induction of the pithball with a negative (first row) and a positive rod (second row):



STATIC ELECTRICITY

INDUCTION

9.11. THE SPARK-PRODUCING FINGER

- Materials:
1. A flat metal candle holder (or dish).
 2. A candle (medium size), a large round balloon.
 3. A wool or flannel cloth.

Procedure:

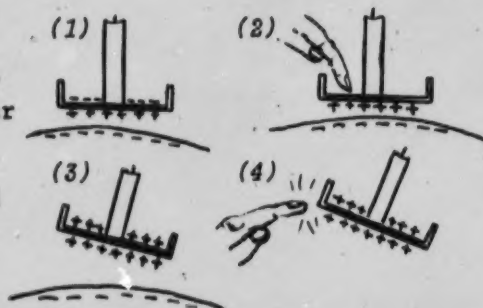
1. Inflate the balloon and rub it vigorously with the wool cloth.
2. Attach the candle to the candle holder, place the candle holder on the rubbed surface of the balloon, using the candle itself as a handle (hold with right hand).
3. Now touch the upper side of the candle holder with a fingertip of the left hand (a small spark may jump to your finger).
4. Lift the candle holder from the balloon, still holding on to the candle with the right hand.
5. Now approach the bottom edge of the candle holder with a fingertip of the left hand (a spark will jump).
6. Steps 2-5 may now be repeated several times.

Questions:

1. Was it actually the finger that produced the spark?
2. Where did the energy originally come from?
3. What type of energy was the original source?
4. What happened when the finger touched the upper side of the holder?
5. What charges jumped from the finger to the holder, when approaching the bottom of the holder?

Explanation:

Rubbing the balloon with the wool leaves the balloon negatively charged. Approaching this with the candle holder pushes all negative charges to the upper side of the holder (1). Touching this upper side will remove the negative charges (2), leaving a positive induced charge on the electrophorus (3). Negative charges will jump from the finger when brought near the bottom edge of the electrophorus (4).

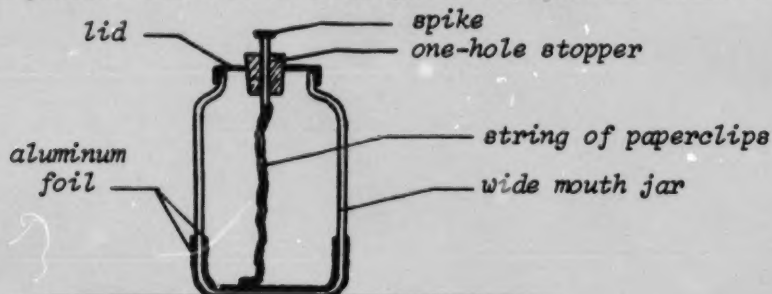


STATIC ELECTRICITY

CAPACITORS

9.12. THE ELECTROSTATIC STORAGE

- Materials:
1. A gallon jar (wide mouth) & lid.
 2. A spike (10 cm nail) & paperclips.
 3. A one-hole stopper, aluminum foil.
 4. A plastic rod & wool cloth (or Electrophorus: Event 9.11).

Procedure:

1. Make a hole in the jar lid the same size as the one-hole stopper.
2. Cover the bottom to about one third of the sides up with aluminum foil, on the inside of the gallon jar.
3. Do the same thing with the outside of the jar (see Sketch).
4. Insert the spike in the one-hole stopper and attach a string of paperclips to the end of it, such that the end of the chain will drag on the bottom of the jar.
5. Now insert the stopper in the hole of the jar lid and close off the jar.
6. Charge up the jar with negative static, by rubbing the plastic rod with the wool and touching the spike (or with the electrophorus: Event 9.11) and do this about 10 times.

Questions:

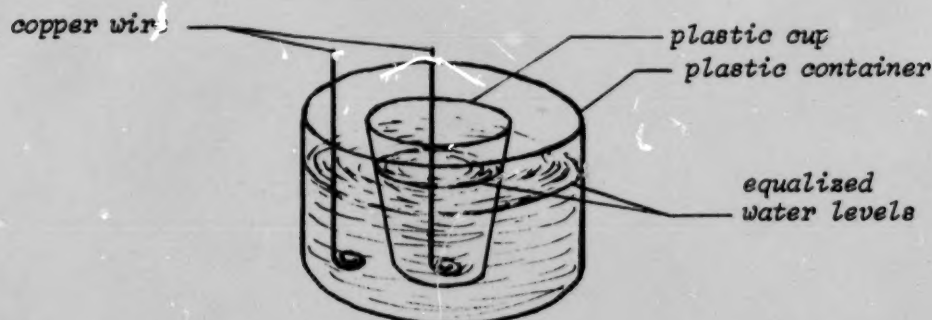
1. What is the purpose of the chain of paperclips?
2. Would the storage jar work without the paperclips?
3. What type of static electricity would we store with the use of the electrophorus from 9.11?
4. What would be the danger if we used too small a stopper?

Explanation:

The two sheets of aluminum foil, separated by the bottom of the jar, act as a capacitor. The charges obtained by rubbing the wool over the plastic rod are small charges, which can be accumulated in this *Leyden Jar*. The purpose of the paperclips is to connect the inner layer of aluminum foil to the spike. It would be much better if the lid were made of insulating material (material that does not conduct electricity: plastic, hard rubber, etc.). With a metal lid, we must use a rather large rubber stopper in order to prevent charges from jumping from the spike to the lid. With the *electrophorus* (Event 9.11) the jar may be charged with 5 or 6 sparks, but with the rod and wool it will take 8-10 times of touching. When the jar is fully charged, we may short the outer foil with the spike with a wire connecting the two, and observe a large spark jump over.

9.13. THE WATER CUP SPARK COLLECTOR

- Materials:**
1. A plastic cup, a plastic container (larger in diameter).
 2. Two pieces of bare copper wire.
 3. A glass rod & silk or a plastic rod & wool.
 4. A plastic or wooden cloth pin.

Procedure:

1. Place the plastic cup in the larger plastic container.
2. Fill the cup 3/4 full with tap water and fill the outer container with water to the same height.
3. Bend the two pieces of copper wire at one end, so that it can stand up-right in the containers. Place one in the center and the other in the outer container, immersed in the water.
4. Charge up the capacitor now with the glass rod and silk, or with the plastic rod and wool, by touching the center wire after every rubbing. Repeat this about 10 times.
5. Hold the wire from the outer container with a cloth pin and move the tip closer to the center wire and observe the jumping of the spark!

Questions:

1. How similar is this apparatus to the Electrostatic Storage (9.12)?
2. In which part of the apparatus do the charges collect?
3. What other equipment may be used to charge up the collector?
4. What is the difference in using glass and silk or plastic and wool?
5. What would we need to increase, if we wanted to collect a much larger electrostatic charge?

Explanation:

This apparatus is very similar to the Leyden Jar (Event 9.12). The only difference is, that the collecting surfaces are now, instead of aluminum layers, water layers that are separated by an insulating layer of plastic: the wall of the plastic beaker. Each of the layers is connected with the bare copper wire, and each one has the opposite charge of the other. The glass and silk will produce positive in the center, and so will the electrophorus (see Event 9.11), whereas the plastic rod and wool cloth will produce negative in the center wire.

CHAPTER 10

HOW IS CURRENT ELECTRICITY CREATED ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

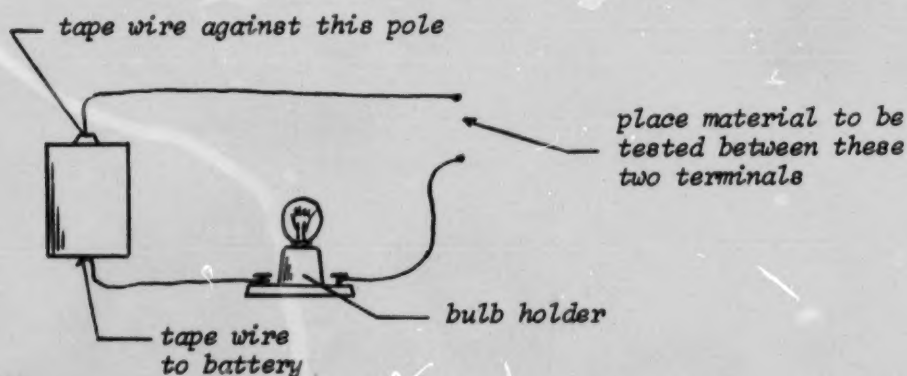
- The conductivity of metals and semi-conductivity of carbon.
- Current electricity can only flow in a completed circuit.
- A circuit may be controlled or broken by switches or fuses.
- Current electricity may be transformed into heat.
- Electricity can be produced from chemical sources.
- A magnetic field exists around a wire which carries electricity.
- A coil of wire can be turned into a strong magnet by electricity.
- Electromagnets have many applications.

CURRENT
ELECTRICITY

CONDUCTIVITY

10.1. MAKE A CONDUCTIVITY TESTER

- Materials:**
1. A battery (dry cell) and masking tape.
 2. A 1.2 volt bulb and bulb holder.
 3. Three short wires (bent out paper clips will do).



Procedure:

1. Connect one pole of the bulb holder to the negative pole of the battery (use masking tape).
2. Connect another wire to the other pole of the bulb holder.
3. Tape one end of the third wire to the positive pole of the battery.
4. The two loose ends are the test terminals. Test the light and when the two loose ends are touching each other, the light should go on.
5. Test any material for conductivity, by placing it between the two loose terminals.

Questions:

1. What should the light do when a conductor is placed between the two terminals?
2. If both terminals are touching one and the same object, and the light does not go on, what does it mean?
3. Which of the following materials are conductors: a penny, dime, nickle, quarter, aluminum foil, paper, wood, glass, the faucet, watch band, gold ring, ruler, pencil carbon, eraser, etc.?

Explanation:

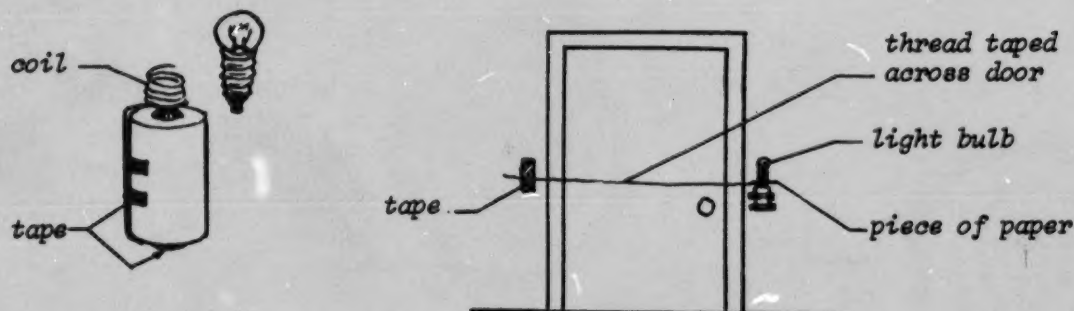
The difference between static and current electricity is, that in the former case there is only a build-up of electric charges, but no flow of charges except in a spark (a short jump of charges). The latter needs a completed circuit for electrons to flow continuously. In the case of the conductivity tester, there is a break in the circuit between the two loose terminals. When a conductor is placed between these terminals, the circuit is completed and the light goes on. When a non-conductor is placed between the terminals, the circuit is still broken, because electrons cannot flow through non-conductors, and thus the light stays off. Objects that are made of metal are all electric conductors. Carbon of a pencil is a partial conductor, or semi-conductor.

CURRENT
ELECTRICITY

CONDUCTIVITY &
CIRCUITS

10.2. THE SECRET BURGLAR ALARM

- Materials:
1. A battery (dry cell).
 2. 1.2 volt bulb and a short solid bare copper wire.
 3. Sewing thread and masking tape.



Procedure:

1. Take the copper wire and wind it along the groove of the bulb and bend the wire around the battery and tape the end of the wire against the negative pole of the battery, (see sketch A).
2. Turn the bulb to the right and make sure the bulb lights.
3. Place a piece of paper between the bulb and the battery.
(Pull it out, and the light should go on.)
4. Tape a thread to the piece of paper (long enough to span across the doorway).
5. Tape the battery plus bulb to one sill of the door and tape the other end of the thread to the other side of the door sill. (sketch B)

Questions:

1. What should the light do if someone comes in the door?
2. What is preventing the bulb from switching on?
3. What other materials may be used in place of the piece of paper?
4. How is a real burglar alarm triggered?

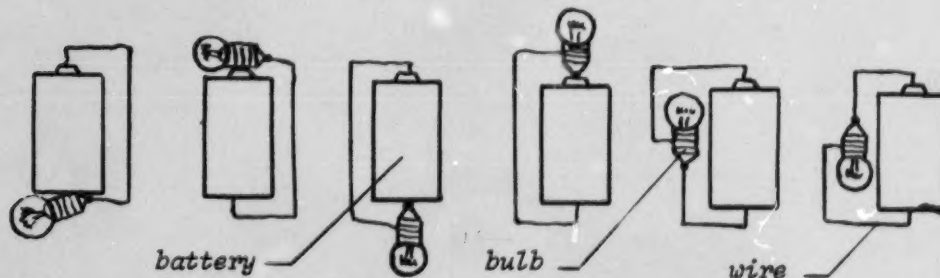
Explanation:

The function of the paper is to prevent completion of the circuit. When the alarm is set the light is not on and when the door is opened or when someone comes in the room the thread and the attached paper is pulled away. This leaves the circuit completed and the light is on. Other materials that may be used to break the circuit are non-conductors like: plastic, cardboard, cloth, etc.

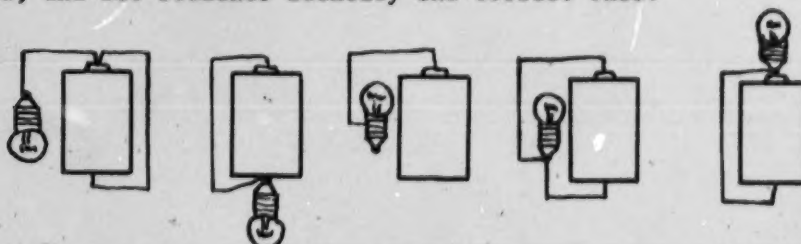
A real burglar alarm is triggered by the breaking of a light or laser beam, which is invisible to the human eye, but needed to prevent the completion of the alarm circuit. Breaking of the light beam thus completes the circuit and the alarm sounds.

CURRENT
ELECTRICITYCONDUCTIVITY
& CIRCUITS10.3. LIGHT THE BULB

- Materials:**
1. A battery (dry cell) & a small bulb (1.2 V)
 2. Two short wires (paperclips or aluminum foil will do).
(a set of materials for each pair of students).

**Procedure:**

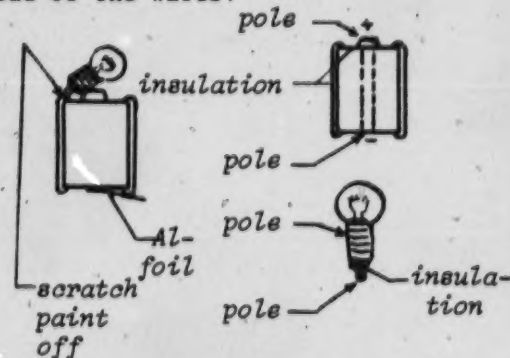
1. Provide each pair of students with a battery (dry cell), a bulb, and two short wires (or bent out paperclips or aluminum foil strips).
2. Ask the students to light the bulb, with two wires, then with one wire.
3. Ask: "In how many ways can you light the bulb?"
4. Place the above circuits intermixed with the following circuits on the board, and let students identify the correct ones.

**Questions:**

1. Will any set-up of the second set of circuits light the bulb?
2. Which of the schematics above are correct to light the bulb?
3. Which two poles of the battery and two poles of the bulb have to be connected to light the bulb?
4. Is it possible to light the bulb without wires or any other materials?
5. What other materials can we use instead of the wires?

Explanation:

As long as one pole of the bulb is connected to either + or - of the battery and the other pole of the bulb to the free pole of the battery, the bulb will light. Without wires, the set-up on the right sketch might work, when the insulation of the rim of the battery is scratched off, and the battery is placed on a piece of aluminum foil (some of the bottom rim paint should be scratched off).

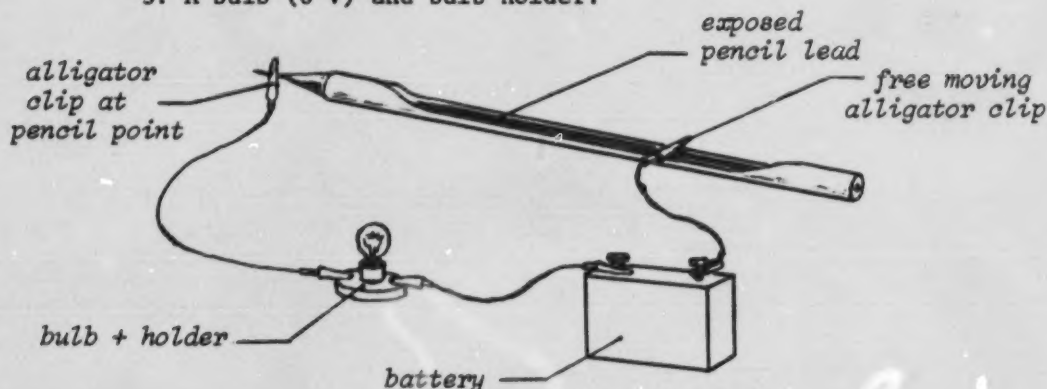


CURRENT
ELECTRICITY

CONDUCTIVITY

10.4. REGULATE THE CURRENT WITH A PENCIL

- Materials:**
1. A long pencil.
 2. A 6 Volt battery & 3 alligator clip leads.
 3. A bulb (6 V) and bulb holder.



Procedure:

1. Cut the wood of the pencil away to expose the lead.
2. Connect the three wire leads with the alligator clips as follows:
 - a. From the pencil point to one pole of the light bulb.
 - b. From the other pole of the light to one terminal of the battery.
 - c. From the other terminal of the battery to the open exposed pencil lead (free moving end of the wire).
3. Hold the free end of the third wire lead and slide the alligator clip over the exposed pencil lead. Observe the light bulb!

Questions:

1. Is pencil lead a conductor of current electricity?
2. Why did the light bulb glow dimmer and brighter?
3. What did we have to do in order to make the bulb glow dimmer?
4. Do you think there is more or less resistance for the current to flow through pencil lead compared to copper wire?

Explanation:

Pencil lead is a *semi-conductor* of current electricity. This means that not all the electrons can flow through, thus the voltage is hereby reduced. The longer the length of the pencil lead is in the circuit, the more the resistance for the electrons to flow through, and so the lower the voltage, with the result that the bulb is glowing dimmer. By sliding the free end of the wire closer to the stationary end of the pencil (pencil point), this resistance gets less and thus it gets easier for the electrons to flow, resulting in a brighter glow of the bulb.

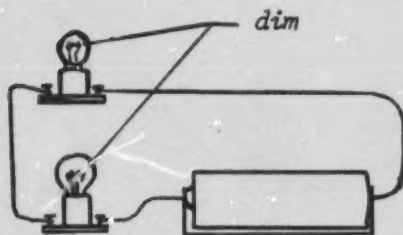
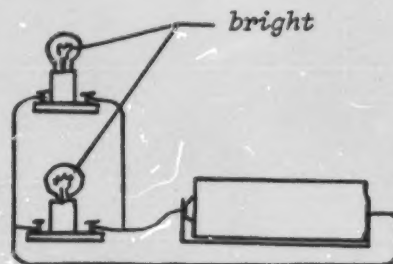
A very long metal wire will have the same effect as the short pencil lead. A variable resistance--a resistance that can be changed at will--is called a *rheostat*. Rheostats are applied in dimmer switches, stove and oven temperature controls, and other appliances requiring current flow regulators.

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CIRCUITS

10.5. THE DIMMER AND BRIGHTER BULBS

- Materials:**
1. A battery (dry cell) and holder.
 2. Two 1.2 Volt bulbs and bulb holders.
 3. Four lengths of copper wire.

Sketch A : Series CircuitSketch B : Parallel CircuitProcedure:

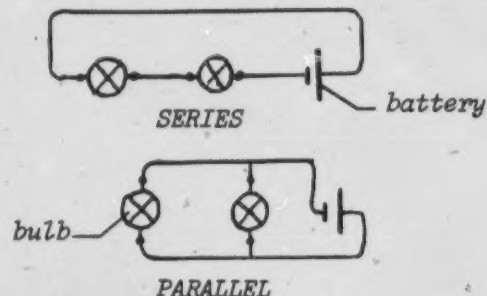
1. Take a battery in its holder and two bulbs in their holders and connect them as pictured in Sketch A.
2. Turn one of the bulbs loose in the socket (both bulbs go off).
3. Change the circuit and connect the wires as pictured in Sketch B (the bulbs burn with a brighter light).
4. Now turn one of the bulbs loose in its socket (only this one bulb turns off and the other stays on).

Questions:

1. Why are the bulbs in the first circuit glowing dimly?
2. Why are the bulbs in the second circuit glowing brightly?
3. What is the reason that both bulbs are turned off when only one is turned loose in its socket in the first circuit?
4. Why does the second bulb stay on in the second circuit, when one bulb is turned off?
5. What type of circuit would we have in our home?

Explanation:

A glowing bulb in an electric circuit gives a certain resistance to the electron flow in the circuit. In the *series* circuit, the bulbs follow one after another in one wire, adding to the resistance in the current flow, and thus dimming the glow of the bulb. In the *parallel* circuit this is not the case. Each bulb is individually connected to the battery, independent from each other. This is the wiring system used in our homes. An example of a *series* and *parallel* circuit is found in the Christmas lights. Those with one wire in between the bulbs are wired in series, whereas those with two wires in between the bulbs have a parallel circuit.

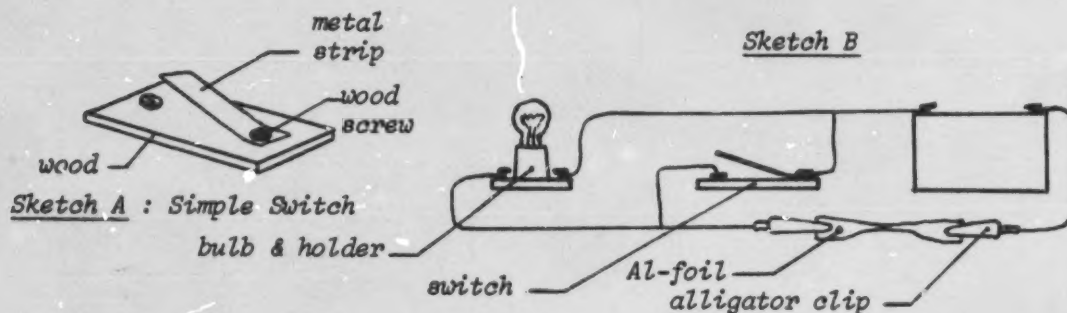


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ELECTRICITY

CIRCUITS

10.6. THE ALUMINUM FOIL FUSE

- Materials:**
1. A strong battery (6V) or five 1.2 V batteries.
 2. Copper wire and aluminum foil.
 3. Bulb (6V) and holder, and simple switch.

**Procedure:**

1. Cut a piece of aluminum foil (a gum wrapper will do) in the shape illustrated in the circuit of Sketch B.
2. Make a simple switch from a piece of wood, a metal strip (or paperclip) and two small wood screws (Sketch A).
3. Connect the aluminum foil fuse, the switch and the light bulb to the battery in a circuit pictured in Sketch B (when the switch is open, the bulb should be on).
4. Now draw students' attention to the light and the fuse: push the switch closed; the fuse blows and the light goes out (even when the switch is released, the light stays out).

Questions:

1. Why does the fuse not blow when the switch is left open?
2. Why does the fuse blow when the switch is closed?
3. What does the switch actually do to the circuit when it is closed?
4. What is the purpose of a fuse in an electrical circuit?

Explanation:

The switch in this circuit has the purpose to short the circuit. When the switch is closed, the current from the battery can flow much faster, because it does not have to pass the bulb. Electric current, just like a flow of water through pipes, seeks the path of lowest resistance. When there are two paths of which one has a higher resistance, the current will flow through the one with the lowest resistance: in this case the closed switch rather than the bulb. The sudden stronger current makes the thin aluminum foil too hot to stay whole and burns off. When the switch is now released, the circuit stays broken, because of the broken fuse, and thus the light stays off until the fuse is restored.

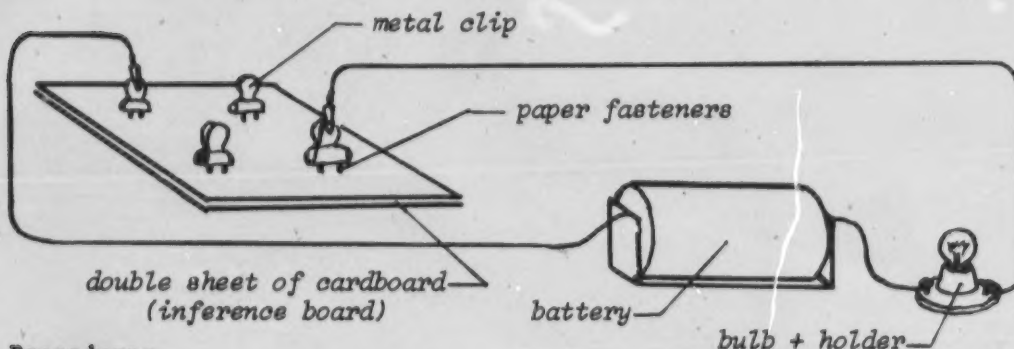
The purpose of a fuse is to prevent the start of a fire in case of a short circuit. This latter can heat the wires so much that the insulation might catch fire. A fuse will break the circuit immediately when shorted.

CURRENT
ELECTRICITY

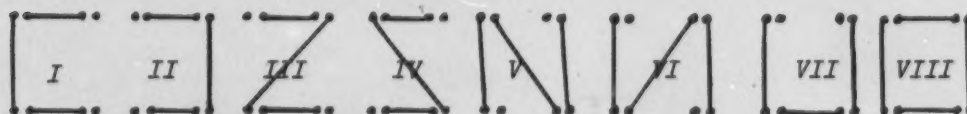
CIRCUITS

10.7. THE INFERENCE BOARDS

- Materials:**
1. Carboard sheets (15x20 cm), paper fasteners.
 2. Metal clips (large), copper wire (bare), masking tape.
 3. Light bulb & holder, battery & holder.
 4. Wire leads with alligator clips.

**Procedure:**

1. Make 4 to 8 different inference boards, by pushing paper fasteners through the carboard sheets, bending the two prongs, connecting the fasteners with the bare copper wire (Sketch below), covering the back with another cardboard sheet (tape together) and placing the metal clips over each pair of paper fasteners. The 8 patterns are as follows:



2. Connect the bulb and battery with the wire leads as in the sketch above and clamp two terminals with the alligator clips (f.i. B & C), take clip A or D (one at a time) off the paper fasteners, and infer the wire pattern from the light bulb's off or on observations.

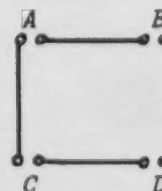
Questions:

1. When the alligator clips are connected to terminal B and C, and the light is on, what would be your inference?
2. With alligator clips on B and C, light on, taking off metal clip A, and the light goes off, what would be your inference now?

Explanation:

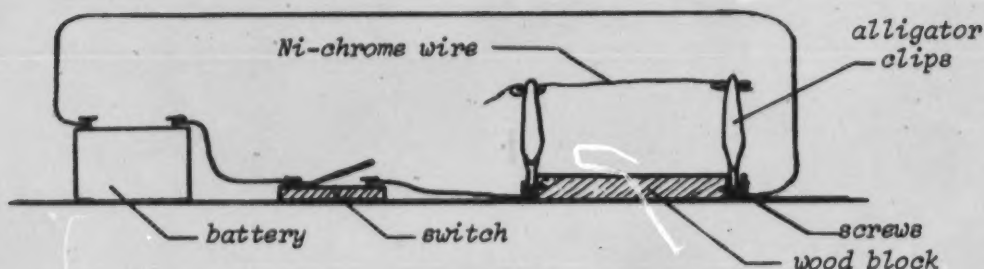
With the alligator clip of the testing instrument on B and C, the light will go on, because the current will pass through A. But as soon as the clip A is taken off, the light will go off. Taking off clip D will not affect the burning light bulb.

The connections behind the cardboard should be soldered.



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ELECTRICITYCIRCUITS
SOURCES10.8. CHANGE ELECTRICITY INTO HEAT

- Materials:**
1. Nickel-chrome wire and alligator clips stand.
 2. A battery (6V), 3 wires, a simple switch.

**Procedure:**

1. Connect the wires in the circuit as outlined in the sketch.
2. Clip the Ni-chrome wire between the alligator clips, making sure that they make connection (by doubling or tripling the wire where it is clipped).
3. Push the switch to complete the circuit and observe the Ni-chrome wire.
4. Show that the wire is actually red hot by touching a piece of paper to the Ni-chrome wire, while keeping the circuit closed.

Questions:

1. What is the original source of energy?
2. What is the electricity changed into?
3. What would a thin copper wire do in place of the Ni-chrome wire?
4. Where do we find an application of this principle?
5. What made the electricity change into heat?

Explanation:

The 6 Volt battery is the original chemical source of energy, which is turned into electrical current. It passes through the Ni-chrome wire and is transferred into heat at that spot. The flow of electrons through the Ni-chrome wire may be compared to the flow of water through a narrow pipe. The current is flowing without resistance through the rest of the circuit, but in the Ni-chrome wire, the flow is hampered because of the small size of the wire (in diameter). The flow of electrons in this part of the circuit creates friction between the electrons and the wire molecules, resulting in the formation of heat.

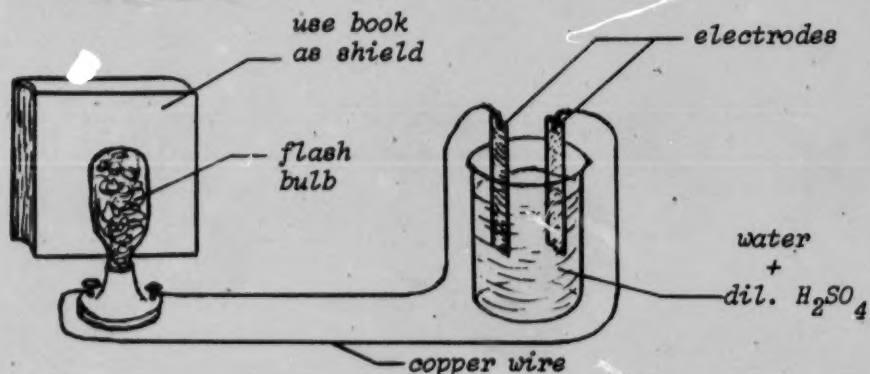
As the melting point of Ni-chrome is much higher than copper, the wire can glow without melting, but if a fine copper wire were used in its place, it would melt and break the circuit as a fuse would. This change of electric energy into heat is applied in electric stoves, ovens, toasters, heaters, dryers, kettles, etc.

CURRENT
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SOURCES

10.9. THE LIQUID BATTERY

- Materials:
1. A copper and a zinc (or magnesium) strip.
 2. Dilute sulfuric acid, copper wire leads.
 3. A beaker, a flash bulb & holder (or 0.2 V bulb).

Procedure:

1. Fill the beaker half full with water and add dilute sulfuric acid till the beaker is 3/4 full.
2. Make small nail holes in one end of each of the electrodes and connect the copper wires from each of the electrodes to the two terminals of the bulb holder (do not dip the electrodes in the beaker yet!).
3. Stand a book in front of the flash bulb (to prevent students from getting blinded by the flash of light).
4. Hold the two electrodes, one in each hand, let students observe, and immerse the electrodes quickly in the liquid. (The electrodes should be gleaming clean: scraping with sand paper may help).

Questions:

1. What made the flash bulb light?
2. What materials made up the source of the electric current?
3. Why was a shield necessary between the bulb and the observer?
4. What triggers the flash in a camera flash?

Explanation:

This battery is normally called a *wet cell*, because liquid is involved. Car batteries are usually wet cells: sulfuric acid and water acting as the *electrolyte* and lead (and lead oxide) as the *electrodes*. In this case the copper and zinc strips were the electrodes. Zinc (or magnesium) having more of a tendency to lose electrons compared to the copper, act together with the H_2SO_4 electrolyte as the source of electron flow.

Without the book as a shield, students might get temporarily blinded by the bright flash, especially when they look directly at the bulb. It is a good precaution to use a shield, as the flash is bright enough to be seen without directly looking at the bulb. When using a regular small bulb, this shielding is not necessary.

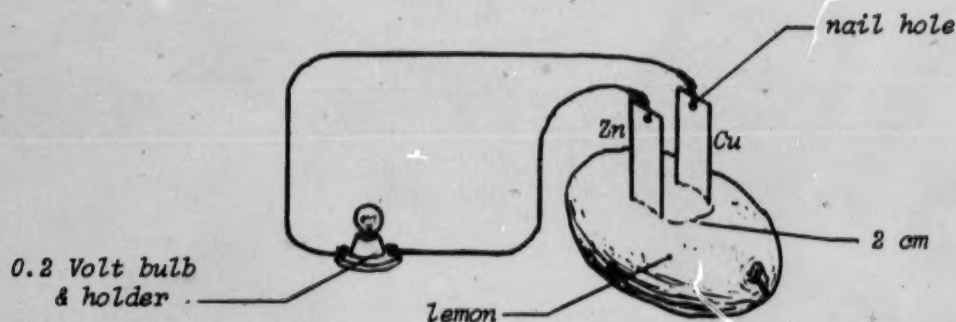
The flash of a camera flash is triggered by the built-in battery, either in the camera, the flash holder, or the flash cube itself.

CURRENT ELECTRICITY

SOURCES

10.10. ELECTRICITY FROM A LEMON

- Materials:**
1. A copper and a zinc strip (electrodes).
 2. Two copper wire leads.
 3. A galvanometer or a 0.2 Volt bulb.



Procedure:

1. Make a small nail hole in the end of the metal strips.
2. Insert the copper and zinc strip into the lemon vertically, about 2 cm apart from each other.
3. Connect the wire leads to each of the electrodes and connect one of the other ends to one terminal of the bulb holder.
4. Get ready with the other loose end of the wire to touch the open terminal of the bulb holder. Before touching it, draw students' attention to the bulb (or galvanometer).
5. Touch the terminal with the loose end of the wire for short moments at a time (the current is so weak that you will not get electrocuted!)

Questions:

1. Where does the current come from?
2. What is current electricity actually?
3. Can we use other metals to make electricity with the lemon?
4. Would two strips of the same metal produce electricity?
5. What other fruit can be used instead of the lemon?

Explanation:

Current electricity is a flow of electrons through a completed circuit of conductors. The source of the electron flow in this case is the combination of copper and zinc strips in the citric acid of the lemon. Zinc has more of a tendency to lose electrons compared to copper, and thus connected through the wires and light bulb, the electrons flow from the zinc to the copper strip.

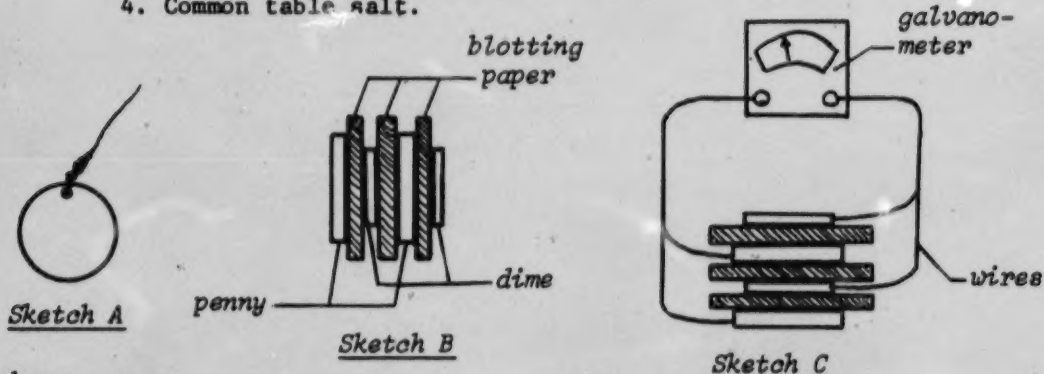
Other metal pairs that could be used to develop potential differences or electromotor forces (EMF), are: copper and silver, copper and iron, copper and magnesium, etc. Other fruit that could replace the lemon are: orange, grapefruit; less potential difference comes from apple, pear and peach. It is the acidity (the citric acid) in the fruit, which is necessary to conduct the electrons from one electrode to the other.

CURRENT
ELECTRICITY

SOURCES

10.11. THE COIN BATTERY

- Materials:
1. Two pennies and two dimes.
 2. Blotting paper or thick paper towel.
 3. Copper wire and a galvanometer.
 4. Common table salt.

Procedure:

1. Clean the coins thoroughly with a brush, soap and water until gleaming.
2. Punch a nail hole close to the edge of each of the four coins, and attach a short and a longer copper wire to the two pennies, and do the same to the two dimes (see Sketch A).
3. Soak pieces of blotting paper in salt water and arrange the pennies and dimes between the blotting paper as in Sketch B.
4. Attach the wires to the galvanometer like in Sketch C. Before completing the circuit, draw students' attention to the galvanometer needle, then touch the terminal with the loose wire. (you will not feel any electric shock, as the currents are just very weak ones).

Questions:

1. Why do the coins have to be cleaned?
2. Where does the electricity come from?
3. What is the source of the electron flow?
4. What is the function of the salt water?
5. Would using more pennies and dimes increase the current?

Explanation:

The dime and the penny act as silver and copper electrodes. The salt water in the blotting paper is the electrolyte needed to get a transfer of electrons from the silver to the copper. In this case, copper has a greater tendency to lose electrons than silver, and a flow of electrons is created from the copper to the silver electrode when the circuit is completed. The sodium (Na^+) and chloride (Cl^-) ions are the electron carriers in the electrolyte. Without the salt, the electrons cannot flow and thus no current is produced.

The larger the surface of the electrodes, the larger the potential difference between the electrodes. The increase in the number of pairs of coins would therefore increase the voltage as well as the current (amperage).

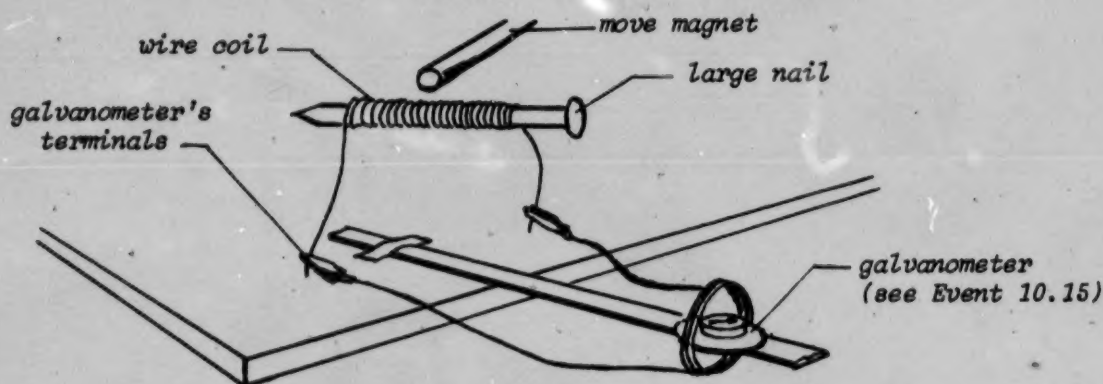
The common dry cell uses carbon and zinc as electrodes, with damp ammonium chloride (NH_4Cl) as electrolyte.

CURRENT ELECTRICITY

SOURCES

10.12. ELECTRICITY FROM A COIL?

- Materials:**
1. Bell wire, a large nail, a strong magnet.
 2. A simple galvanometer (or compass and coil of wire).



Procedure:

1. Wrap the bell wire around a large nail (or steel bolt) with at least 20 windings to make the coil.
2. Attach the ends of the coil to the terminals of the galvanometer (the simple galvanometer of Event 10.15 may be used).
3. Now take the strong magnet and move one pole of it back and forth near the coil, while observing the needle of the galvanometer.
4. Turn the rod magnet end for end and move the other pole back and forth near the coil. What does the galvanometer show?

Questions:

1. After reversing the magnet, what happens to the galvanometer?
2. What is the source of energy that is converted to electricity?
3. What factors are influencing the increase of the current output?
4. Where do we find this principle applied in daily life or industry?

Explanation:

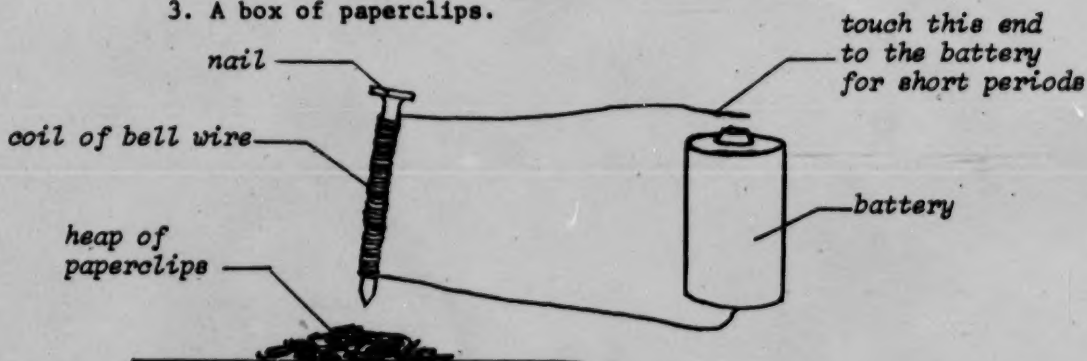
This is an example of an *electromotive source of electricity*, where mechanical energy is converted into electrical energy. By moving the pole of the rod magnet back and forth near the coil, an electric current is produced in the coil, which is detected by the galvanometer (an instrument to detect weak currents). By moving the magnet in one direction along the coil and then back again, we can see that the deflection of the galvanometer needle changes direction, meaning that the current *alternates* from one direction into the other. The electrical generators in power plants are based on the same principle, where coils are moving in a strong magnetic field to produce *alternating current (AC)*. The bicycle dynamo is an example of a generator that produces *direct current (DC)*.

CURRENT
ELECTRICITY

ELECTROMAGNETISM

10.13. THE NAIL MAGNET

- Materials:
1. A large nail (10 cm long), bell wire (1 m long)
 2. A 6 V battery (or 3 1.2 V D-size batteries)
 3. A box of paperclips.

Procedure:

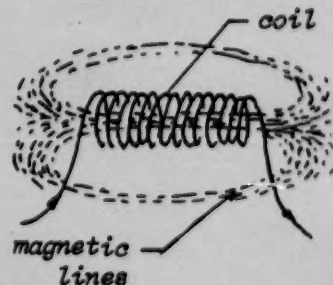
1. Wind the bell wire around the nail (about 20 times).
2. Scrape the insulation off from the ends of the wire and place the paperclips in a heap on the table.
3. Have someone hold the nail above the heap of paperclips, touch the two ends of the wire to the battery poles and let the student raise the nail. How many paperclips were picked up?
4. Wind another ten loops of the wire around the nail and complete the circuit again. Have the students count the number of clips picked up.
5. Increase the number of batteries (by placing them in series and connecting + pole to - pole of the next battery). Have students count the number of paperclips picked up.

Questions:

1. What made the coil become a magnet?
2. What effect did increasing the number of windings have on the magnetic attraction force of the nail?
3. What did two or three batteries in series do to the magnetic force?
4. Would removing the iron core of the coil weaken or strengthen the magnetic attraction?
5. How does the magnetic attraction of the coil change when the core is changed into a wooden, glass, or other kind of rod?

Explanation:

When an electric current flows through a coil, it acts as a magnet. By placing an iron rod inside the coil, the magnetic lines pass through the iron rod and the coil becomes a much stronger magnet, as long as the electric current flows through the coil. The more windings in the coil, the stronger the magnetic force. This force is also directly proportional to the magnitude of current.

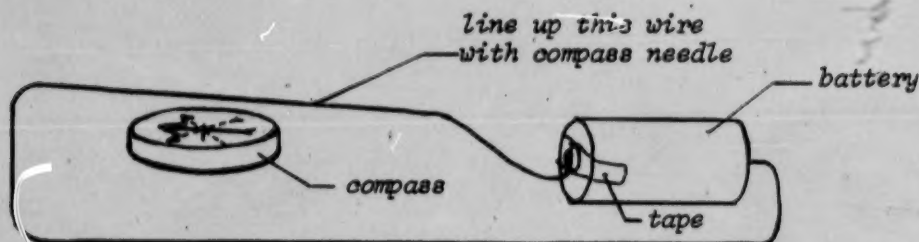


CURRENT
ELECTRICITY

ELECTROMAGNETISM

10.14. THE DEFLECTING COMPASS

- Materials:**
1. A D-size battery (1.2 V).
 2. Copper bell wire (and a simple switch).
 3. A magnetic compass.



Procedure:

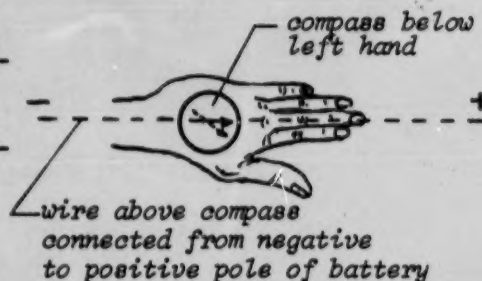
1. Distribute one compass, one battery and a length of bell wire to each pair of students.
2. Instruct students to do the following:
 - a. Line up one wire coming from the positive pole of the battery with the compass needle by holding it above the compass (tape the wire end to the battery).
 - b. Bring the other end of the wire to the negative pole of the battery but do not complete the circuit yet (use a switch if available).
 - c. Pay attention to the compass needle, touch the battery with the loose end of the wire for short periods.
 - d. Place the compass above the wire, complete the circuit, what happens?

Questions:

1. What did the compass needle do when the circuit was completed?
2. How did the compass needle deflect when it was above or under the wire?
3. What is the reason for the compass needle to move?
4. What would the compass needle do were a magnet to approach it?
5. What can we conclude about the surroundings of an electric current?

Explanation:

This demonstration shows that a *magnetic field* exists around an electric current. As soon as the circuit is completed, by touching the loose end of the wire to the battery, the North-pointing needle of the compass will deflect to the left (the way it is set up in the sketch). The left hand rule may be discovered by the students: When holding the left hand over a compass, such that the flow of electrons is from the wrist to the fingertips, the North-pointing needle deflects along the opening thumb. (Make sure that the palm is facing the compass).

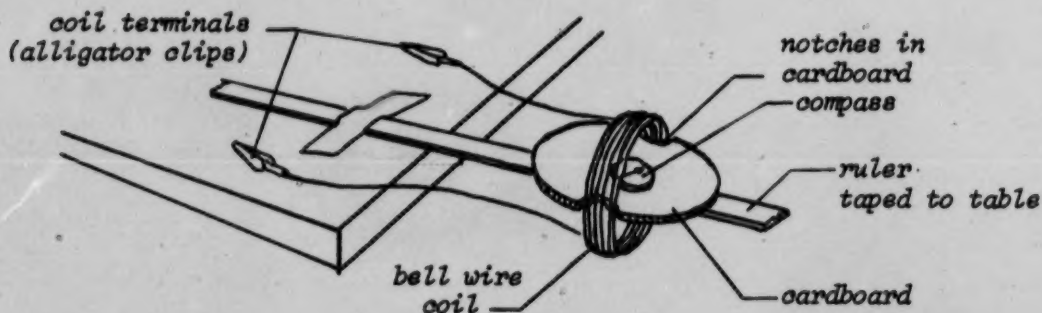


CURRENT
ELECTRICITY

ELECTROMAGNETISM

10.15. THE SIMPLE GALVANOMETER

- Materials:
1. A small compass (magnetic), bell wire, two alligator clips.
 2. Cardboard, plastic ruler (30 cm) and masking tape.



Procedure:

1. Cut out a circle (diameter about 10 cm) out of a sheet of cardboard, and make two notches opposite each other.
2. Wind the bell wire in a coil of at least 10 windings, with the same diameter (10 cm) and fit it in the two notches perpendicular to the cardboard circle.
3. Tape a ruler to the table top and tape the cardboard with the coil to the protruding end of the ruler (see Sketch).
4. Connect alligator clips to the two ends of the coil and leave this on the table top.
5. Tape the small compass in the center of the cardboard and line up the needle with the coil (by moving the ruler).
6. You are ready to test the galvanometer: any small current through the coil will move the compass needle.

Questions:

1. What makes a compass needle move in general?
2. What does the coil turn into when current passes through it?
3. What will make the galvanometer more sensitive?
4. What does a galvanometer measure?

Explanation:

When an electric current is led through a coil, the latter is turned into a magnet. A magnetic field is thus created around the compass, when a small current passes through the coil, and this field deflects the compass needle. The more windings in the coil, the stronger the magnetic field and thus the more sensitive the instrument.

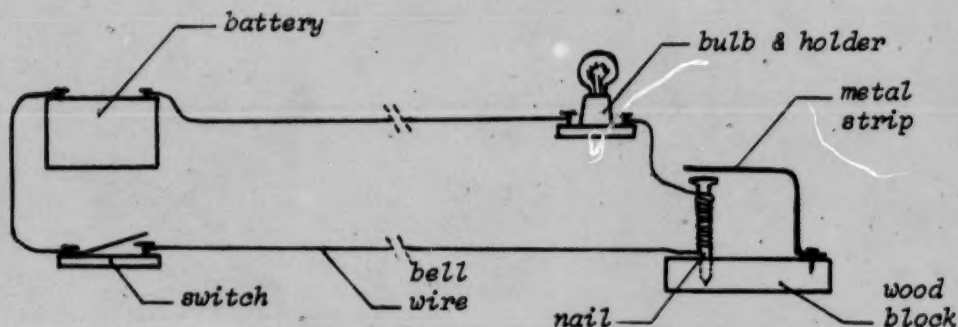
The stronger the current passing through the coil, the stronger the magnetic field created around the coil and the more the compass needle will deflect. A larger deflection therefore indicates a larger current. When the current is passed in the opposite direction through the coil, the magnetic poles switch and the compass needle deflects in the opposite direction. The instrument therefore, not only measures the strength but also the direction of weak currents.

CURRENT
ELECTRICITY

ELECTROMAGNETISM

10.16. THE SIMPLE TELEGRAPH

- Materials:**
1. A simple switch, nail and bell wire.
 2. A battery (6 V) and bulb (and holder).
 3. A small block of wood, strip of tin, and small screw.

**Procedure:**

1. Hammer the nail $\frac{1}{2}$ way into the block of wood, wind about 20-30 loops around the nail, and further connect the bell wire to the bulb, battery, and switch (see circuit in the sketch).
2. Bend the tin strip (cut from a tin can) in an S-form and screw it to the other end of the wood block, such that a small gap is left between the strip and the nail head.
3. Push on the simple switch for short periods of time to close the circuit and observe the light go on and the metal strip move down.

Questions:

1. What made the metal strip bend down towards the nail?
2. Would the metal strip still be dipping down, even when this 'nail switch' and light are several km away from the simple switch?
3. What does the light suggest about the circuit, when it is on?
4. Does the light bulb have to be part of the circuit in order for the metal strip to be attracted to the nail?

Explanation:

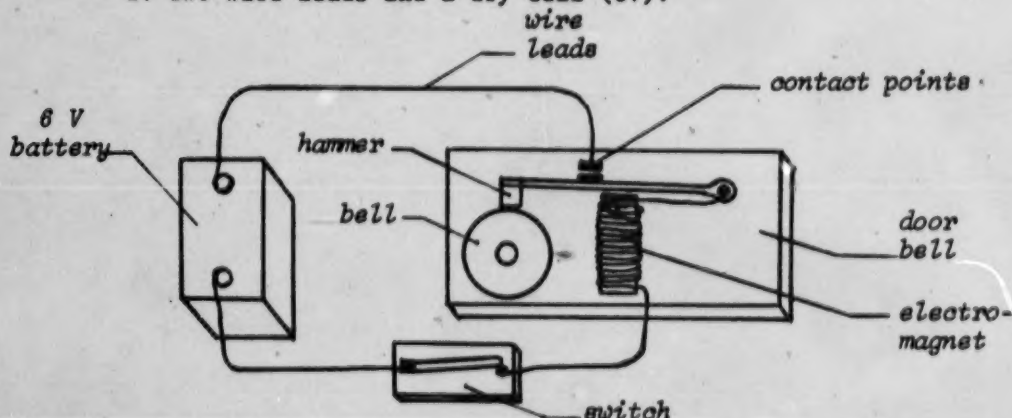
The closing of the simple switch completes the circuit, resulting in a flow of electrons through the coil of wire around the nail. This produces a magnetic field around the coil as the coil turns into a magnet, attracting the metal strip down towards the nail head. The completed circuit also makes the light go on. Without the light in the circuit, the metal strip still bends down towards the nail when the simple switch is pushed down. The completed circuit also makes the light go on. Whenever the simple switch is released, the circuit is broken, and the coil stops acting as a magnet, resulting in the release of the metal strip. As the strip has some spring action properties, it springs back up, as soon as attraction forces disappear. This is the principle of the telegraph, where Morse codes are sent over long distances. Ships at sea communicate by Morse codes in terms of long and short flashes of light.

**CURRENT
ELECTRICITY**

**CIRCUITS &
ELECTROMAGNETISM**

10.17. TURN ELECTRICITY INTO SOUND

- Materials:**
1. A simple doorbell and switch.
 2. Two wire leads and a dry cell (6V).



Procedure:

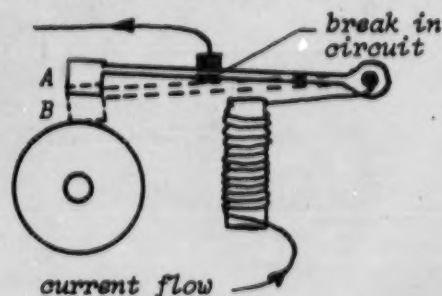
1. Take the cover off the doorbell and expose the electromagnet, bell, hammer and contact points.
2. Connect one wire to one terminal of the simple switch, and the other wire with a wire lead (with alligator clips) to the dry cell.
3. Attach the other wire lead between the simple switch and the free pole of the battery (circuit is pictured in Sketch).
4. Complete the circuit now by pushing the simple switch.

Questions:

1. What is accomplished in the circuit by holding down the simple switch?
2. As soon as electricity runs through the coil, what does it become?
3. What will the hammer do to the circuit when it hits the bell?
4. Why does the hammer move back towards the contact point?

Explanation:

When the simple switch is pushed down, the circuit is completed, and electricity flows through the coil. This turns the coil into a magnet, pulling the hammer towards it and in doing so it hits the bell. In the B position (see sketch on right) against the bell, the hammer actually breaks the circuit and the coil does not attract the hammer any more; thus it flips back towards the contact point, resulting in closing the circuit again, and the whole cycle starts over. This on and off switching of the circuit happens very rapidly and a vibration of the hammer results.



CHAPTER 11

HOW DOES LIGHT BEHAVE ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

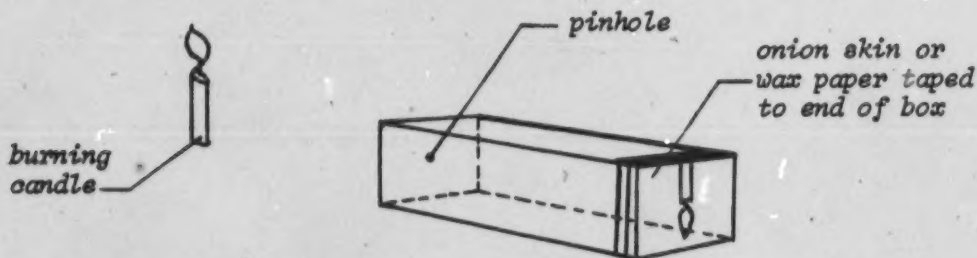
all in relation to the following sub-concepts:

- Light travels in straight lines.
- The image of an object is seen exactly the same distance behind the mirror as the object is in front of it.
- The angle of incidence is the same as the angle of reflection.
- Light is refracted towards the normal when coming from a less dense medium into a denser medium.
- Real images may be formed by holding a lens between a light source and a paper card.
- White light is defracted into a spectrum of colors when passed through a prism of denser material.

LIGHT

TRAVELS IN
STRAIGHT LINES11.1. MAKE A PINHOLE CAMERA

Materials: 1. A shoebox and onion skin paper (chin paper).
2. A candle.

Procedure:

1. Take the shoe box and cut out the side of one end of the box and tape the thin onion skin paper to it.
2. Make a small round hole in the other end of the box and tape the lid to the box. (Make the hole a little larger than a pin hole).
3. Point the hole-end of the box towards a window or a light source: lamp or candle, and observe the image on the thin paper (prevent light from falling on the outside of the onion skin paper).

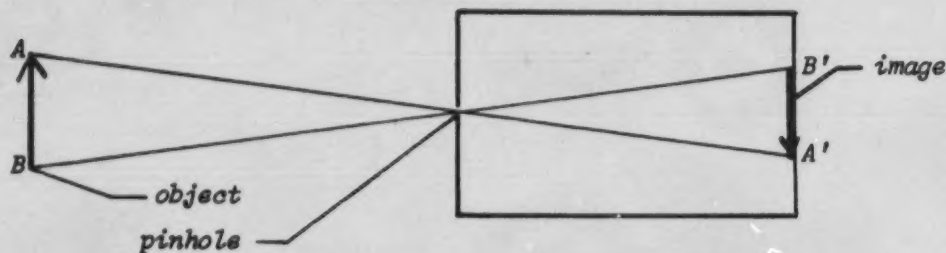
Questions:

1. What do you observe on the onion skin paper?
2. Why is the image on the paper always upside down?
3. What would happen to the image if the pinhole were enlarged?
4. How do the light rays travel from the object to the image?

Explanation:

Light travels in straight lines. This why the image is always inverted. The light from point A of the object travels in a straight line through the pinhole to point A' on the onion skin of the box, and point B to Point B' thus inverting the image. When the pin hole is enlarged the image will get blurred. The smaller the hole (aperture in a camera), the sharper the image.

The onion skin paper at the end of the box may be replaced with a photographic plate and exposed for a short time. (The box has to be held steady).

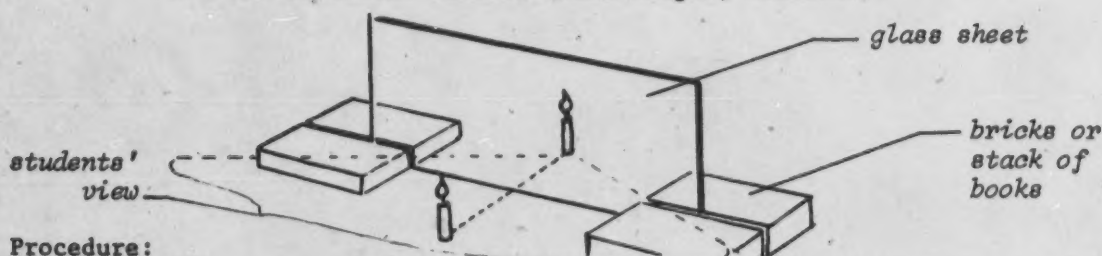


LIGHT

REFLECTION

11.2. THE COOL CANDLE FLAME

- Materials:** 1. A rectangular piece of window glass.
2. Two identical candles (same height, diameter).

**Procedure:**

1. Mount the glass sheet vertically between four bricks or four stacks of books. (Or hold it in two mounts of molding clay).
2. Fix one candle in front of the glass sheet on the table (10 cm measured on the perpendicular to the glass).
3. Fix the second candle in the back of the glass sheet on the table exactly the same distance from the glass). Block the student's view of the first candle with a large book or folder, and light *only* this candle. (do as if you light both candles), then remove the folder. (Students should sit in places, such that they cannot see the second candle without looking through the glass sheet--students' view, in sketch).
4. Place your (or a student's hand) above the second (unlit) candle for a very short while and withdraw. Increase this time 2 or 3 seconds (accompanied with an 'ouch' for dramatic effect).

Questions:

1. Why can you hold your hand above the second candle?
2. Where does the second candle have to be placed?
3. Why is it necessary to cover the students' view when lighting the first (front) candle?
4. Why can't the students see the second candle without looking through the glass sheet?
5. What happens if the second candle is not exactly the same distance from the glass sheet as the first?

Explanation:

It is essential that the students think that both candles are lit; this is why the front candle has to be blocked from the students' view. This is the same reason why students may not see the second candle in plain view. Once the student knows that the candle behind the glass sheet is not lit, the whole effect of the demonstration is lost.

Both candles have to be placed exactly the same distance from the glass sheet, so that the image of the front candle will coincide with the rear candle. If the rear candle is just a trifle off this exact spot, it will show a double image and again the effect of the demonstration will be lost.

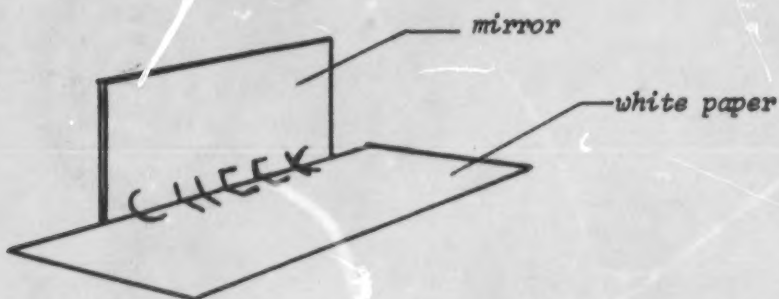
This shows that the image of an object in a mirror is located behind the mirror, exactly the same distance from the mirror as the object is in front of it.

LIGHT

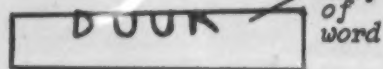
REFLECTION

11.3. FUNNY REFLECTIONS

Materials: 1. Unframed square or rectangular mirror (for each pair of students).

Procedure:

1. Print the following words each on a separate piece of blank paper in large even capital letters. CHEEK, BIKE, DECIDE, BOX, CHICK, CHOKE, BOOK, HIDE, CODE, DOCK, COOKIE.
2. Cut each piece of paper in half, right through the middle of each word printed on, leaving the lower half of the word on the paper.
3. Now place the mirror vertically against the paper (perpendicular on the table) and look in the corner of the paper and the mirror.
4. Do this for each one of the words.

Questions:

1. Will this work with any printed word?
2. Which of the letters, when cut in half, will appear whole with the mirror above it?
3. Which letters, when cut in half vertically, will give the other half in the mirror, when the half letter is held against it?

Explanation:

This activity will provide the student with the ability to recognize symmetrical objects and printed letters. It gives the student an opportunity to manipulate spatial relations. The image in the mirror shows that all images are actually formed behind the mirror.

It is only with the letters: B, C, D, E, H, I, K, O and X, that the above activity can be carried out. All other letters will not give the upper half in the mirror. The following can be cut vertically in half and the other half will show up in the mirror, when held against it: A, H, I, M, O, T, U, V, W and X, Y. This activity gives the students an idea of *symmetry* and *symmetrical* shapes.

LIGHT

REFLECTION

11.4. HOW HIGH TO PLACE THE MIRROR?

- Materials:**
1. A meter long narrow mirror or several smaller mirrors.
 2. A meter stick.

**Procedure:**

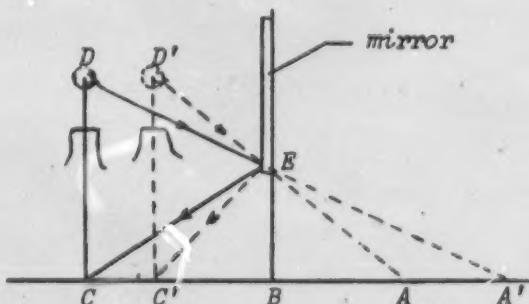
1. Pose the students with the question: "How high do I have to hang the mirror in order to see all of myself including my shoes?"
2. Record the students' predictions of the distance the mirror should be above the floor.
3. Let two students hold the mirror against the wall, a third student looks at her/himself in the mirror, and a fourth measures the maximum height of the mirror off the floor.
4. Attach the mirror at that height and let all the students see themselves in the mirror.

Questions:

1. Does the distance, from where you stand to the mirror, affect the image of yourself in the mirror?
2. How high off the floor does the mirror have to be hung to see your feet in the mirror when standing in front of it?
3. Would a shorter person have to move the mirror in order to see his/her feet?
4. Can you draw the paths of light rays that you see coming from your shoes?

Explanation:

Because the image of the person is exactly the same distance behind the mirror ($AB=BC$), the height BE is always half the height of the person ($\frac{1}{2}CD$). It does not matter where the person stands in front of the mirror. The height BE is not affected by the distance BC .



11.5. LOOK AT YOURSELF AS OTHERS SEE YOU

Materials: 1. Two square or rectangular mirrors without frame
(one set for each group of 6 students).

*two mirrors
held perpendicular
to each other*

Procedure:

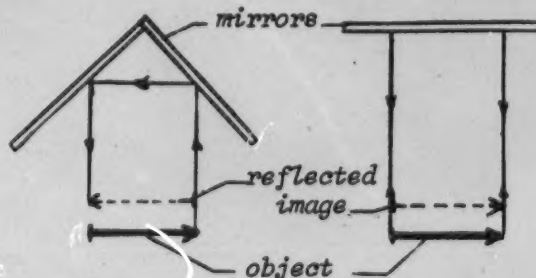
1. Have one student stand the two rectangular mirrors perpendicular to each other on the table, facing away from him.
2. Let each student observe himself in the two mirrors by looking in the corner (joint) of them, and let them touch their hair with one of their hands or wink an eye.
3. Now let the student holding the mirrors place them in one plane (in each other's extension) and let the students observe themselves again.

Questions:

1. Why did the left hand appear on the right in the perpendicular mirrors?
2. How do the light rays travel from object to mirror and back to the observer's eye?
3. What happened to your image when the mirrors were straightened?
4. How are the light rays travelling now?

Explanation:

The light rays of the object (which is yourself) are reflected in 90° angles from one mirror to the other and then back to the eye. In a regular straight mirror, the rays bounce right back to the eye, without being reflected to another mirror. With the two mirrors perpendicular to each other, anything on the left of the object is reflected to the right hand side. All points of the object on the left side is seen on the right and vice versa. (see sketch on right).

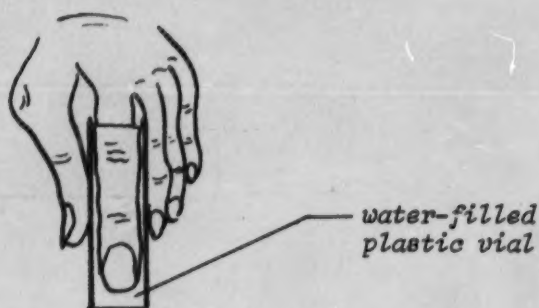


LIGHT

REFRACTION

11.6. THE SWOLLEN FINGER

Materials: 1. A plastic vial (about 2 cm diameter)
(an olive jar is quite suitable)

Procedure:

1. Fill the vial or jar about $3/4$ full with water.
2. Immerse your forefinger in the water and show the difference in size with the other fingers.
3. Pour out the water and compare the size of the fingers again without the water in the vial.

Questions:

1. Why does the forefinger look so much larger than the other fingers?
2. Did the finger look larger without the water in the vial?
3. What is the basic cause for magnification?
4. Would we get magnification by looking through a rectangular jar?
5. What other liquids can we use in the vial?

Explanation:

The basic reason why the finger looks so much larger is that the water in the vial acts like a magnifying lens. The shape of the vial resembles the shape of a convex lens. If the container were a flat rectangular container, this lens effect would be lost.

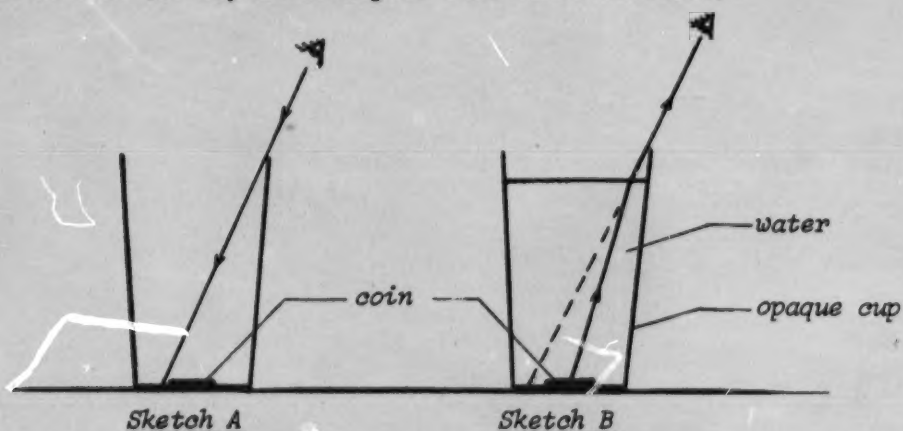
The material inside the container may be compared with the glass, which the magnifying lens is made of. Other materials that have high *refraction indices* may be used to obtain this same effect.

LIGHT

REFRACTION

11.7. THE REAPPEARING COIN

- Materials:**
1. An opaque cup (foam or polystyrene).
 2. A coin (or any small object that sinks in water).

**Procedure:**

1. Let the students gather around the cup placed on a low stool.
2. Place a coin in the opaque cup and let the students move their heads down from where they can see the coin, so that they just cannot see it (because it disappears behind the rim of the cup), and let them hold their eyes steady at the spot (Sketch A--the coin may be taped to the bottom of the cup, so it won't slide when water is poured in).
3. Pour water into the cup until it is almost full: coin reappears!

Questions:

1. What made the coin disappear before the water was poured?
2. What made the coin reappear?
3. Did you have to move the position of your eyes to see the coin again?
4. What can you tell about the path of the light rays coming from the coin?
5. What other liquids can be used instead of water?

Explanation:

The eyes were positioned, such that the light rays coming from the coin were blocked by the rim of the cup. By adding water to the cup, these same light rays from the coin are now refracted away from the normal, as it travels from denser to a less dense medium (see Sketch B & C).

The normal is the line perpendicular to the surface separating the two media through which the light ray travels. Other liquids with high refractive indices, usually the denser ones, may replace water in this case.

This phenomenon is the reason why some deep waters seem to look shallow.

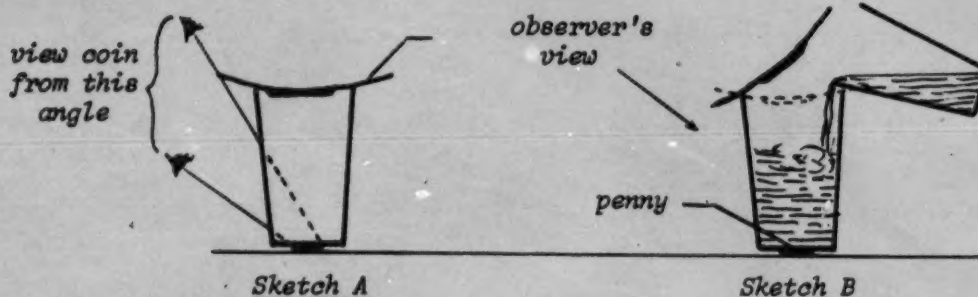
Sketch C

LIGHT

REFRACTION

11.8. THE INVISIBLE PENNY

- Materials: 1. Two regular drinking glasses.
2. A small saucer and a penny (or other coin).

Procedure:

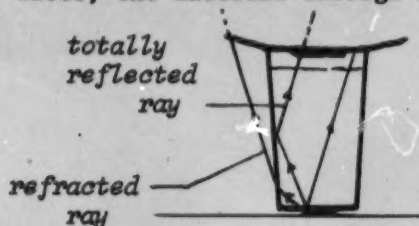
1. Fill one of the glasses almost full with water.
2. Cover the empty glass with the saucer and place the covered glass on the coin. Let the students observe the coin *only* from the side of the glass (Coin can be seen in sketch A).
3. Fill this glass with water, tilting the saucer towards the observing students (see sketch B), and place back the saucer.
4. Ask students: "Where did the penny go?"
Move the glass to the side and reveal penny.

Questions.

1. What made the penny or coin invisible?
2. Where do the light rays of the coin travel?
3. Why do we need a saucer to cover the glass?
4. Why does the saucer have to slant towards the observer?
5. What other objects may be used in place of the coin?

Explanation:

The coin is still visible with the empty glass and saucer on top of it, because the light rays are not refracted by the air filled glass, and the coin can be seen from the side of the glass. By filling the glass with water, the material through which the rays are travelling is denser and thus, when they hit the side of the glass they are being totally reflected or refracted very closely to the side of the glass. The saucer on top of the glass prevents seeing these rays and thus seeing the coin. The saucer has to be tilted towards the observer, while filling the glass with water, for the same reason.



Other objects in place of the coin would be, anything which is flat and thin, and that can be covered by the bottom of the glass; like a stamp, a thin button, a piece of paper, a washer, etc.

LIGHT

REFRACTION

11.9. THE WATERDROP MAGNIFIER

- Materials:** 1. A roll of wax paper.
2. A small cup.

Procedure:

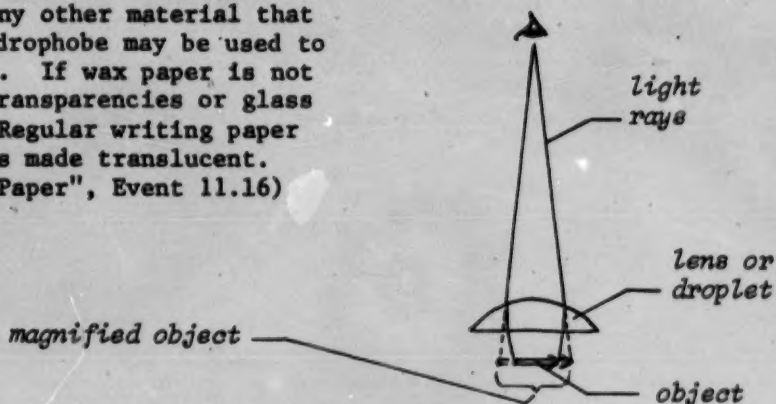
1. Tear off about 10 cm wide strips of wax paper from the roll and distribute this to each student or to each pair of students.
2. Let the students place the wax paper over small print or anything small that they want to see magnified.
3. Come around with water in a cup and put a drop on the wax paper—make a circle about 1/2 cm in diameter.
4. Let the students try out drops with different diameters.

Questions:

1. How can a waterdrop act as a magnifier?
2. Which drop magnifies better, the smaller or the larger?
3. What property of the drop makes the amplification larger or smaller?
4. What other material could we use to replace the wax paper?

Explanation:

The waterdrop on the wax paper stays rounded on the top (convex) because of the water-repellant properties of the paper (hydrophobe). This is why the waterdrop resembles the shape of a magnifying glass. The smaller the waterdrop, the stronger the curvature, in other words the more curved the upper surface is, and thus the stronger the magnification. Any other material that is translucent and hydrophobe may be used to replace the wax paper. If wax paper is not available, overhead transparencies or glass sheets may be used. Regular writing paper might be used which is made translucent. (see "The Peek-a-boo Paper", Event 11.16)



LIGHT

REFRACTION

11.10 THE GLASS ROD MAGNIFIER

- Materials:** 1. Glass stirrers (one for each or a pair of students).
 2. Plastic vials or olive jars.

Procedure:

1. Distribute the glass stirrers to each or each pair of students. If glass rods are not available, fill plastic vials or empty olive jars with water, replace the top, and pass it around.
2. Let students place the glass rod or water-filled cylinder over printed material and look through the transparent cylinder.
3. Now let them hold the rod or cylinder about 1 cm away from the printed material (print is turned upside down).

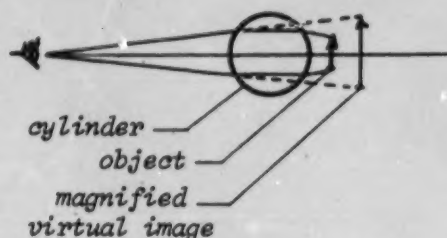
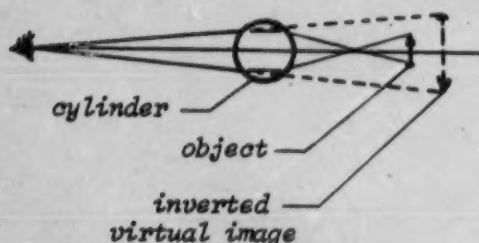
Questions:

1. What made the rod or cylinder act like a magnifying glass?
2. How far from the printed letters could we hold the rod or cylinder before getting distortions in the letters?
3. What is necessary for the letters to be seen upside down?
4. How are the light rays travelling from the object to the eye?
5. What type of image is the magnified or inverted image?
6. Would a regular magnifying glass also invert the image?

Explanation:

The best way to clarify the magnification and inverting of the image is by studying the light rays coming from the object and the ones that are detected by the eye. These latter are drawn in the sketches below.

In both instances the image is a *virtual image*, one which is seen by the eye but not projected on the paper (which would be a *real image*).

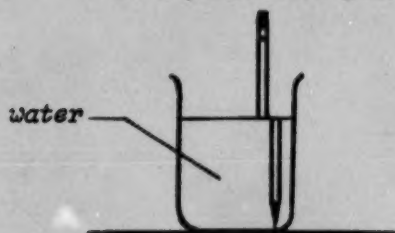
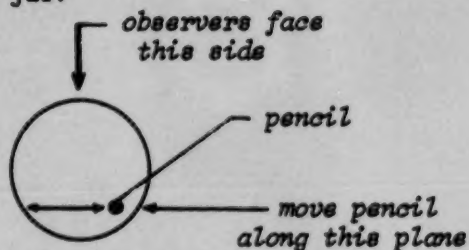


LIGHT

REFRACTION

11.11. THE BROKEN PENCIL

- Materials:
1. A medium size beaker or glass jar.
 2. A pencil (or pen or straw).

Sketch ASketch B : Top view of beakerProcedure:

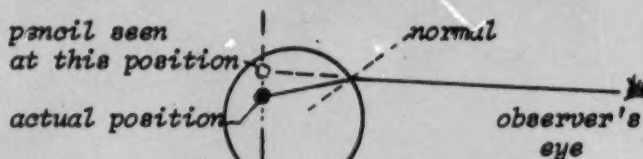
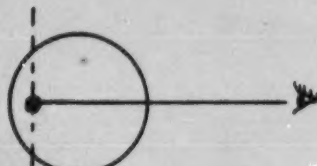
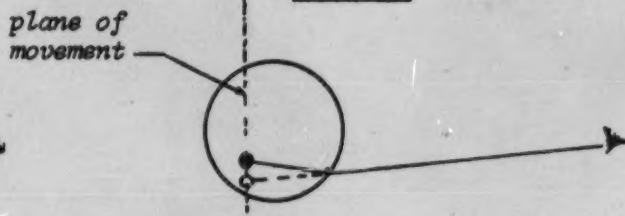
1. Fill the beaker or jar about 2/3 full with water.
2. Take a pencil, pen or straw and immerse it vertically about half way into the water, and say to the students: "I have now broken the pencil (pen or straw)".
3. Move the pencil back and forth along a vertical plane somewhat closer to the demonstrator (see Sketch B) and parallel to the observer's eyes.

Questions:

1. Is the pencil actually broken?
2. Why does the pencil look like it is broken?
3. Would we get the same effect without the water?
4. What other liquids can be used for this demonstration?
5. What other objects can we use to immerse?

Explanation:

The light rays from the pencil travel from a denser medium (water) to a less dense medium (air). This makes the light ray refract away from the normal (see Sketch 1), and the pencil is seen at the extension of the refracted ray.

Sketch 1Sketch 2 : Pencil in centerSketch 3 : Pencil on other side

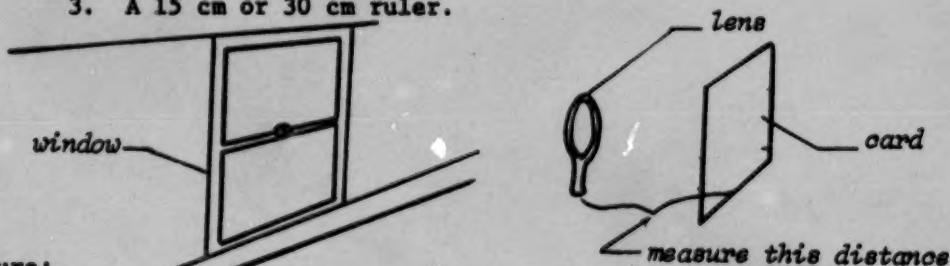
When the pencil is in the center of the beaker the ray is not refracted, because the light ray is travelling along the normal (Sketch 2). Sketch 3 shows the light ray from the pencil on the opposite side of the beaker.

LIGHT

REFRACTION

11.12 PRODUCE AN IMAGE OF THE WINDOW

- Materials:** 1. Two or three identical magnifying glasses.
 2. A three by five paper card (7x 12 cm).
 3. A 15 cm or 30 cm ruler.

**Procedure:**

1. Divide the students in groups of three and distribute to each of the groups a set of the above materials.
2. Let one student hold the lens parallel to the window (if there is no window, hold the lens horizontally parallel with the light in the classroom).
3. Let the second student hold the paper card behind the lens and move the card slowly farther away from the lens until a sharp image of the window (or light source) is formed.
4. As soon as a sharp image is formed on the card, let the third student in the group measure the distance between the lens and the card (image distance).
5. Place two lenses together and see how the image distance changes, and three lenses and see how the image distance changes with the number of lenses (measure from the middle of the combined lenses to the card for the image distance).

Questions:

1. What kind of lens is the magnifying glass?
2. How did the image distance change with the number of lenses?
3. What other objects can we use to produce an image of?
4. Would a near or far sighted person use glasses that can produce positive images like the magnifying glass?

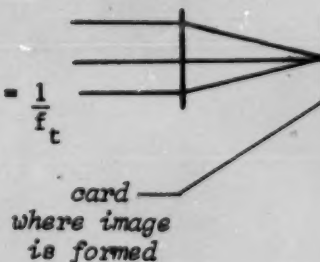
Explanation:

Any magnifying lens is either a double convex or single convex lens. Far sighted people wear convex lenses, and their glasses may be used to produce the same images like magnifying glasses do. As the light rays from the window are almost parallel, the image is formed at the focal point of the lens. Doubling the lens means cutting the image distance in half, as $\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f_t}$

in which f_1 = focal distance
 of lens number 1

f_2 = focal distance
 of lens number 2

f_t = focal distance of total system

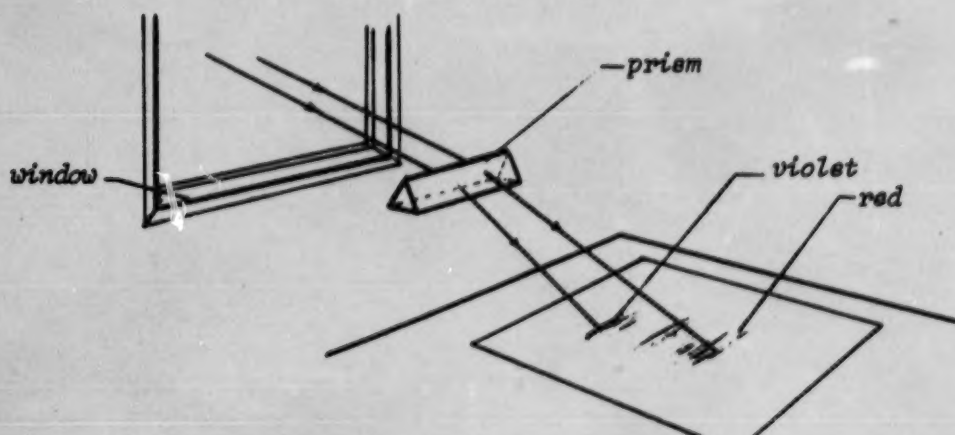


LIGHT

DEFACTION

11.13. MAKE RAINBOW COLORS

- Materials:
1. A triangular prism (glass).
 2. A blank piece of paper and sun rays.

Procedure:

1. Place a blank sheet of paper on the table top where the sun rays shine through the window.
2. Hold a triangular glass prism in the sun rays and turn it around its lengthwise axis until rainbow spectrum falls on the blank paper.

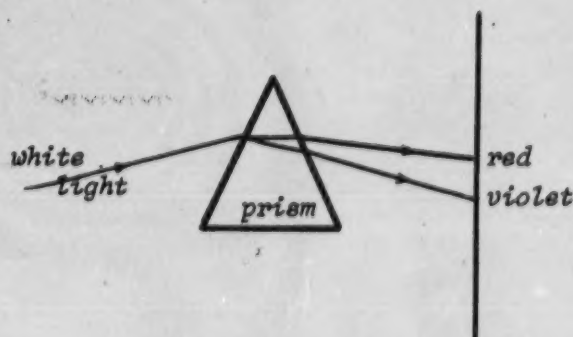
Questions:

1. How can white light give the colors of the rainbow?
2. What are the colors of the rainbow?
3. Which color is bent most? (farthest away from the straight line?)
4. What source can we use instead of sun rays?

Explanation:

White light is made up of the rainbow colors: violet, blue, green, red, yellow and orange. The violet is *refracted* or bent most, and the red is bent the least (see sketch on right).

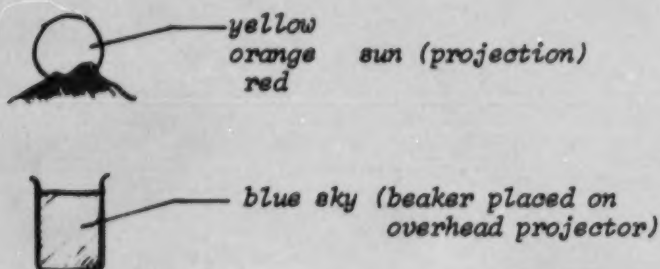
This is why the sky stays blue when the sun sets in the west and becomes red. The moisture in the atmosphere would act as prisms and scatter or *defract* the blue light out. Viewing the sun rays from 90° angle, the color will appear blue (sky) whereas looking directly into the setting sun, the color is red.



LIGHT

REFRACTION
DEFACTION11.14. THE SIMULATED SUNSET

- Materials:** 1. A beaker or glass jar.
2. Sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) and concentrated sulfuric acid (H_2SO_4)

Procedure:

1. Cut a circular hole in a large piece of paper with the same diameter as the beaker or jar, place it on the overhead projector and a water-filled beaker over the hole.
2. Dissolve a scoop of sodium thiosulfate in the water until no crystals can be distinguished in the water.
3. Pour a few ml of concentrated sulfuric acid in the solution, stir, stand back and observe.
4. When the color of the beaker (seen from the side) starts to turn bluish draw students attention to the color of the sun (projection) and the color of the sky (side view of beaker). (When the sun's color gets orange-red, a torn piece of paper may be pushed under the beaker to simulate a mountain).

Questions:

1. How do you think the bluish color in the beaker was created?
2. Why was the sideview of the beaker blue and the projection of it yellow or orange?
3. How is this demonstration similar to the actual sunset?
4. Why does the sun get red when it sets in the west?

Explanation:

White light is *dispersed* or *defracted* into the colors of the rainbow if it hits a prism. When the sun sets in the west we are looking through a much thicker layer of atmosphere compared to noon time. This means that

○ sun at noon



observer on earth

○
sun
in west

when we look to the west, we are looking through more dust and moisture particles. Each of these particles acts like prisms, scattering white light into red at one end of the spectrum and blue

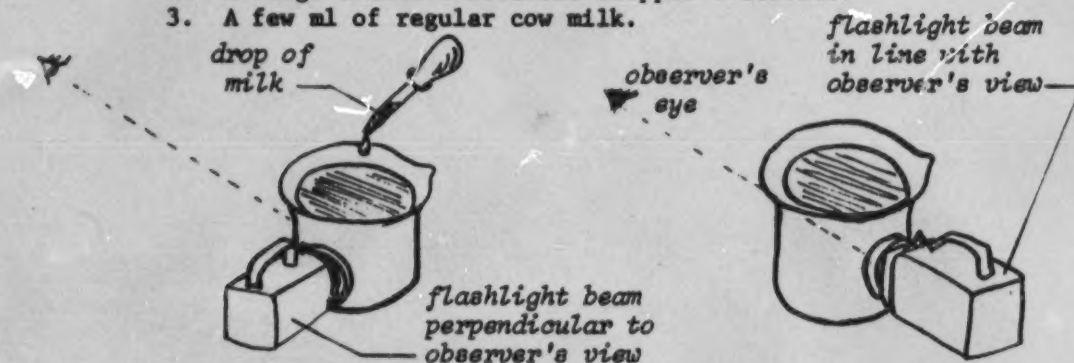
at the other end. Blue has the shortest wavelength and refracts with the largest angle. The reaction of $\text{H}_2\text{SO}_4 + \text{Na}_2\text{S}_2\text{O}_3$ precipitated sulfur (S) slowly out of the solution, simulating the increasing concentration of the dust and water particles.

LIGHT

DEFACTION

11.15 THE CONFUSED FLASHLIGHT

- Materials:**
1. A strong flashlight.
 2. A large beaker & medicine dropper & stirrer.
 3. A few ml of regular cow milk.

**Procedure:**

1. Fill the beaker nearly full with water.
2. With the medicine dropper, place one drop at a time of milk in the water and stir.
3. After each drop of milk added to the water, shine the flashlight through the water by holding it on the side of the beaker: let the light beams shine perpendicular to and into the student's view.
4. Keep adding the drops of milk to the water until the light shone into the student's view becomes red.

Questions:

1. What made the color of the light change?
2. What purpose does the milk have?
3. If the water were the earth's atmosphere and the flashlight were the sun what can the milk droplets be equated with?
4. Which of the colors do you think are refracted most? Which the least?

Explanation:

Increasing the milk droplets in the water is like increasing the water and dust particles in the atmosphere. When the sun moves to the west, approaching sunset, the atmosphere through which we are looking is much thicker. This means that we are actually looking through more dust and water particles. When we look to the west during sunset, we look directly into the sun rays, seeing the sun as a red ball. Looking up towards the sky when the sun is in the west, still leaves the sky blue. The sun rays are now perpendicular to the direction of our view. This difference in color is caused by the refraction of the blue light. The shorter the wavelength (blue), the more it is bent or refracted by the milk droplets. The light with the longer wavelength (red) is not as much refracted and this is why the light from the flashlight is red when we look directly into it (through the beaker with milk). (See event 11.14).

LIGHT

TRANSLUCENCY vs OPAQUENESS
REFLECTION11.16. THE PEEK-A-BOO PAPER

- Materials:**
1. Any kind of writing or typing paper.
 2. Regular frying oil (motor or machine oil will do).
 3. Paper towel.

**Procedure:**

1. Distribute sheets of paper to each one of the students.
2. Dip a corner of paper towel in the oil and come around to each of the students.
3. Make an oil spot in the center of each of the papers.
4. Give the students some paper towel, and let them wipe the excess oil off the oil spot.
5. Let the students look through the spot by placing the paper over printed or written material.
6. Let the students hold the paper against the light and compare the lightness and the darkness of the spot with the rest of the paper.

Questions:

1. How can oil make opaque paper translucent?
2. What does it mean in terms of light rays when something is opaque or translucent?
3. Why is the oil spot dark compared to the rest of the paper when the light falls on the paper?

Explanation:

The oil penetrates all the pores and fibres of the paper when it touches it. This makes the paper completely impregnated with oil and thus more uniform for the light to pass. Thus the light rays penetrate the oil spot and get reflected by the rest of the paper. This is why the oil spot looks darker, because the light rays are not reflected back. When the light source is behind the paper the opposite happens: light passes through the spot and it hits the observer's eye, whereas the rest of the paper blocks the light and appears darker.

CHAPTER 12

WHAT ARE THE PROPERTIES OF SOUND ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

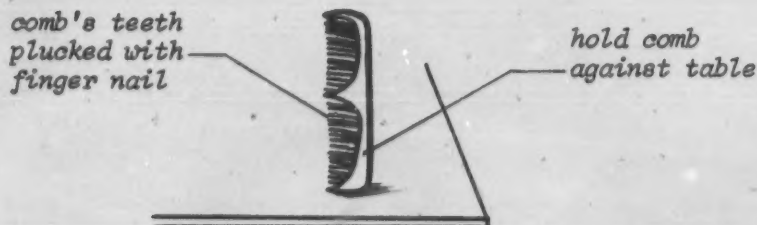
all in relation to the following sub-concepts:

- Sound is produced by vibrating objects.
- The loudness of sound is determined by the distance from the source, the intensity of the vibration, and the surface area of the vibrating object.
- The pitch of a note is determined by the mass of the vibrating object: the larger the mass, the lower the pitch.
- In resonance, the resonating object has the same frequency of vibration as that of the sound source.
- Sound does not travel through a vacuum.
- Sound travels faster through liquids and even faster through solids compared to gases.
- The speed of sound through air is around 340 m/s.

SOUND

LOUDNESS
PITCH12.1 WHICH AMPLIFIER WORKS BEST?

Materials: 1. A cheap polystyrene comb for each student.

Procedure:

1. Hold a comb in the air and pluck the teeth with your fingernail.
2. Ask students: "How can I amplify the sound?"
3. Hold the end of the comb against the table top and pluck again.
4. Distribute different combs to each of the students and let them try to hold it against different material in the class and listen which of them gives the best amplification.
5. Point out to the students that the different lengths of the teeth give different pitches (simple tunes might be plucked by the teacher).

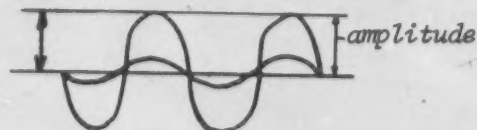
Questions:

1. How did the sound get amplified?
2. Why do we hear the sound louder when the comb is held against other materials?
3. Which factors are influencing the loudness of a sound?
4. What material is the best amplifier for the comb?
5. What made the different pitches in the plucking of the teeth?

Explanation:

In holding the comb against the table top while plucking the comb's teeth, it was not only the teeth and the comb that were vibrating but the whole table top vibrated with it. This means an increased surface of the vibrating object, which is the main reason for an increasing loudness or an amplification. The factors that are affecting the loudness of a sound are:

1. distance from sound source; 2. the amplitude of the wave, i.e., how hard the teeth are plucked; 3. the surface area of the vibrating object.



SOUND WAVE

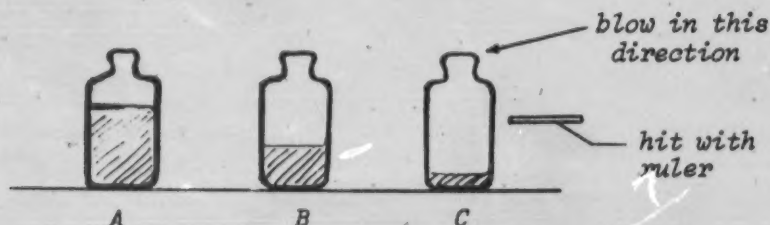
In general wood sheets and wooden boxes are the best materials for quality in sound amplification. This is why sound boards (for the piano), guitar and violin bodies, and speaker boxes are all made out of wood.

SOUND

PITCH

12.2. THE REVERSING PITCH

- Materials:**
1. Three identical empty bottles.
 2. A wooden stick or ruler.

Procedure:

1. Fill the three identical bottles with different amounts of water, and ask the students: "Which will give the highest tone when I hit it on the side with the ruler?"
2. Lift the bottle with 2 fingers at the neck and hit the side of each bottle with the ruler and listen to the pitch of the tone.
3. Now ask the students: "Will bottle C always give the highest pitch?"
4. Blow over the bottle mouth, by placing your lower lip on the bottle rim and blowing a narrow stream of air almost horizontally over the mouth. Listen to the tone/pitch.

Questions:

1. What was vibrating when the bottles were hit on the sides?
2. What produced the tone when the bottles were blown into?
3. What is generally affecting the pitch of a tone?
4. Would different liquids of the same height in the bottles affect the pitch of the tone? When hitting the bottle? When blowing over the bottle opening?

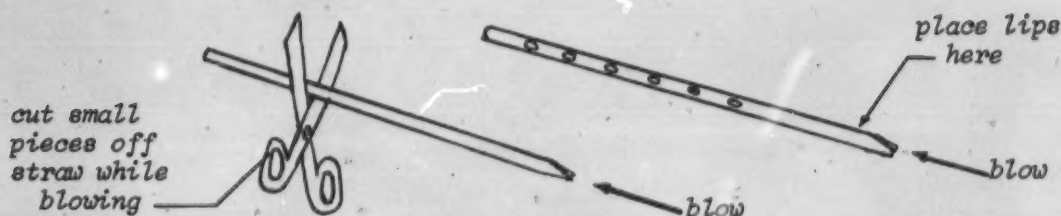
Explanation:

When the bottles were hit on the side with the wooden ruler, the bottle and the water vibrated to produce the sound pitch. The more water there was in the bottle, the lower the pitch. When blowing over the bottle mouth, the air above the water in the bottle vibrated to produce the tone. The larger the column of air in the bottle, the lower the pitch. If we generalize over these two events we can say that, *the more the mass of the material vibrates, the lower the pitch it produces*. This is why the lower and deeper tones on the guitar or piano are coming from the larger and longer strings. By shortening the strings (by placing the finger on a fret), the higher the pitch obtained.

By using different liquids in the bottles, but filling them to the same height, the pitch would probably be different when hit on the side because of the different masses of the liquids, but stay the same when blown over the mouth (because the air column stays the same).

12.3. THE STRAW OBOE

- Materials:
1. Two plastic drinking straws.
 2. A pair of scissors.

Procedure:

1. Cut small holes on one side of a straw, about 1 to 1.5 cm apart from each other.
2. Flatten one end of both straws and cut mouth triangle pieces out. 
3. Place this end of the straw with holes in the mouth, holding your lips just where the cut ends, and blow until an oboe sound is produced. (Shifting the straw somewhat in or out of the mouth might help obtaining the sound.)
4. Place three fingers of the left hand on the farthest three holes and three fingers of the right hand on the nearest three holes of the straw; and open or close holes for the different pitches.
5. Now blow the straw with no holes. Make the oboe sound, take the pair of scissors and cut small pieces off the straw while blowing.

Questions:

1. What was actually producing the sound?
2. What pitch did we get when all holes were closed, compared to when all holes were open?
3. What does opening or closing a hole in the straw really mean in terms of vibrating an air column?
4. Which musical instruments are based on this principle?

Explanation:

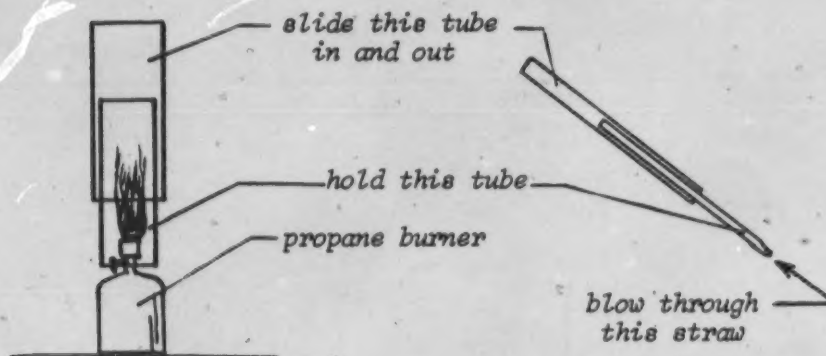
This demonstration especially shows that the pitch of a note is determined by the length of vibrating air. By cutting the end of the straw we are actually making two reed-like protrusions, which when air is blown through them, will vibrate and produce the oboe sound. The air column in the straw is vibrating with it and produces the pitch. With the holes in the straw we are able to make the vibrating air column longer or shorter, by either closing or opening a hole or several holes at a time.

This principle is applied in the flute, clarinet, oboe, saxophone, and their varieties in soprano, alto, tenor and bass instruments.

SOUND

RESONANCE
& PITCH12.4. THE PIPE AND STRAW TROMBONES

- Materials:**
1. Two rigid plastic tubes (one slightly larger in diameter than the other so that they can slide into each other, about 40-50 cm in length each).
 2. Two straws (plastic drinking), with the same specifications as above.
 3. A propane torch or Bunsen burner.

**Procedure:**

1. Light the propane torch or Bunsen burner and turn it to the largest setting with the air valve open.
2. Hold one of the rigid tubes vertically and lower it slowly over the flame until a resonating tone is produced.
3. Slide the larger tube up and down over the first one while holding them both over the flame (trombone effect).
4. Flatten one end of the straw and cut small triangle pieces out of each side to make a straw oboe (see Event 12.3)
5. While blowing through this oboe, producing the tone, slide the other straw over the first one in and out (trombone effect).

Questions:

1. How was the resonating tone in the rigid tube produced?
2. What changed the pitch in the sliding tubes?
3. What produced the tone in the straw oboe?

Explanation:

The heat of the flame in the tube suddenly expands the air in it and the air begins to oscillate up the tube, resulting in a resonating tone; a standing wave is created in a tube with open ends. The longer the tube, the longer wavelengths are produced in the standing wave and thus the lower the tone. The same goes for the sliding straws, except that the sound is produced in the standing wave and thus the lower the tone. The same goes for the sliding straws, except that the sound is produced by the vibrating reeds. These are made to vibrate by blowing the air stream between them.

SOUND

RESONANCE
& PITCH12.5. THE SINGING GLASS

- Materials:
1. A wine glass (or any other thin drinking glass with a smooth rim).
 2. A little vinegar or dilute acid.

Procedure:

1. Wash your hands with soap and place the wine glass on the table.
2. Dip the fore-or middle-finger in a little vinegar, hold the wineglass steady with the other hand (hold base down on table) and rub the rim of the glass with the dipped finger.
3. The rubbing should be done rather slowly (if the finger slips without giving off a sound, then either the glass rim is greasy or your finger is not quite clean).
4. Pour a little water in the wine glass and rub again. Notice the pitch change.

Questions:

1. What is the purpose of the vinegar?
2. Why do the hands and glass have to be clean?
3. What is the finger actually doing when it rubs the glass rim?
4. What is the pitch doing when water is added to the glass?

Explanation:

When the finger is rubbing against the rim of the glass, it is not supposed to just slide over it, but it catches and slides in very quick succession. It is just like hitting the side of the glass with a hard object, softly and in very quick succession. It almost works like a bell hammer. As soon as the first few vibrations are produced, they make the glass *resonate*, because the pitch produced is exactly the same as that of the glass itself.

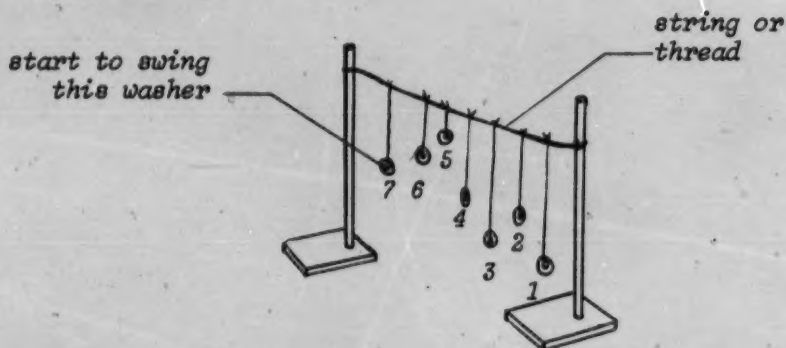
By adding water to the glass, the vibrating mass increased and thus the pitch got lowered.

SOUND

RESONANCE

12.6. THE TUNED-IN WASHERS

- Materials:**
1. Two upright stands and 7 identical washers
 2. Light string or sewing thread.

**Procedure:**

1. Place the two upright stands about 50cm apart and attach a string between them at the same height.
2. Now tie the short lengths of string to the seven washers.
3. Hang the washers on the horizontal string at the following lengths:
 washer No.1 - 20 cm., No.5 - 5cm,
 washer No.2 - 15 cm., No.6 - 10cm.
 washer No.3 - 20 cm., No.7 - 15cm.
 washer No.4 - 15 cm., (somewhat farther apart).
4. Start to swing washer No. 7 and observe the other washers.

Questions:

1. Why did washer No. 2 and No. 4 swing with No.7?
2. If washer No. 2 were swinging first, which one would swing with it?
3. If washer No. 1 were swinging first, which one would swing with it?
4. How can we compare this event with a sound source and resonating objects?

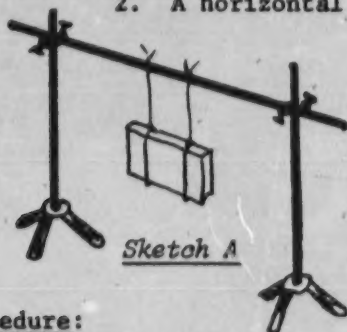
Explanation:

This demonstration is another excellent illustration of the phenomenon of *resonance*. When washer No. 7 starts to swing, washers Nos. 2 and 4 will swing with it. Washer No. 7 can be compared with the source of vibration and washers Nos. 2 and 4 are "tuned in" with or have the same frequency of vibration as washer No. 7. The same happens when washer 2 or 4 is started with the swinging first. The washers that have the same string length will swing with the original "swinger". So when washer No. 1 is started to swing, then only washer No.3 will swing with it.

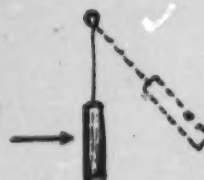
In resonance, the resonating object has to have the same frequency of vibration as the source. Sometimes the source of vibration can be the object itself and then it will increase its own vibrations. This was the case with the collapsing Tacoma bridge in Washington State, which started to vibrate because of a high wind that blew against the bridge.

12.7. THE SWINGING BOOK

- Materials: 1. A paperback pocketbook.
2. A horizontal bar stand and string.



blow against
book with
short puffs

Procedure:

1. Tie two strings to the paperback pocketbook and hang it from a horizontal bar stand (see sketch A).
2. Hold the book about 45° from the vertical line out and ask the students: "Would I be able to blow against the book until it is this far out? (Anticipated answer: NO)".
3. Let the book hang back vertically and blow with huffs in phase with the swings of the book. (Just like pushing someone on a swing in the park).

Questions:

1. Why is it not possible to blow the book to 45° from the vertical line with one huff?
2. What is most important to get the book swinging higher and higher with the huffs?
3. How can we stop the book from swinging without touching it?
4. How can we compare the swinging of the book and the blowing, with sound and resonance?

Explanation:

This is an excellent demonstration to illustrate what *resonance* actually is. When we deal with resonance there is always a source or *origin of vibration* (sound) and an object which is *resonating* with the source of vibration.

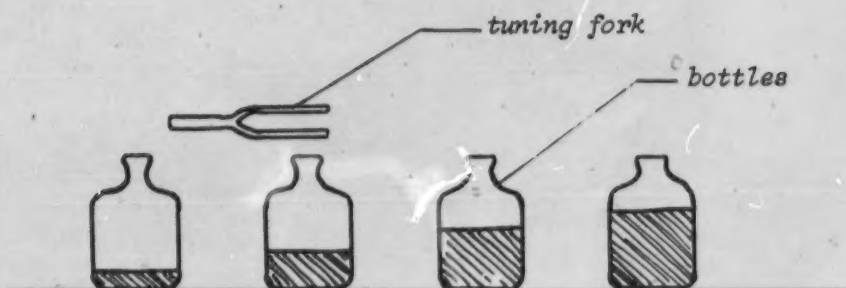
The huffing against the book can be compared with the source of vibration and the swinging of the book as the object which resonates with the source. When the huffing is in phase with the swinging book, it will swing higher and higher. In sound terms: when the sound source has the same *frequency* as the vibrating object, it will resonate with the sound source. In order to stop the swinging of the book, the huffing has to be done out of phase or in opposite phase with the swinging. Again, in terms of sound we would say: to stop the object from resonating, the source has to have a different frequency than the vibrating object, or the object should vibrate with a different frequency than the source of vibration.

SOUND

RESONANCE

12.8. THE SINGING BOTTLE

- Materials:
1. Three or four identical bottles.
 2. A tuning fork.

Procedure:

1. Place the four bottles on the table and fill them with different amounts of water.
2. Strike the tuning fork and listen to the tone.
3. Fill one of the bottles with just enough water, so that the air column above the water (when blown into) will vibrate with the same tone as the tuning fork.
4. Place this bottle back in row with the other bottles, strike the tuning fork and hold it over each of the four bottles (stopping a second above each one, then moving on to the next).

Questions:

1. Which bottle is "singing" with the tuning fork?
2. Why are the other bottles not "singing" with the tuning fork?
3. How can we make the other bottles "sing" too?
4. What is it that makes the bottle resonate with the tuning fork?
5. Where do we find this event applied in daily life?

Explanation:

Since only one bottle's water height was adjusted such, that the air above it would vibrate with the tone of the tuning fork, this bottle is the only one that is *resonating* with the tuning fork. The columns of the other bottles were either too long or too short to "sing" or *resonate* with the tuning fork. The *frequency* of the tone in these latter bottles is not the same as that of the tuning fork, and thus they do not vibrate with it. For a further explanation of resonance see Events 12.6 & 12.7.

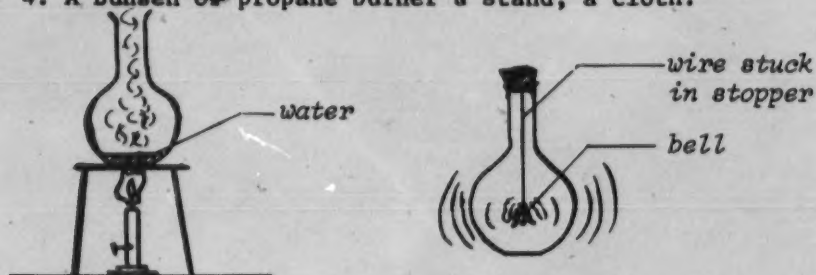
An application of this event in daily life is encountered when a certain tone is sounded in front of a guitar or open grand piano; only certain strings that have the same pitch or octaves thereof, will resonate with the original tone or pitch.

SOUND

MEDIUM OF TRAVEL

12.9. THE SOUNDLESS BELL

- Materials:**
1. A round-bottomed flask (or flat-bottomed).
 2. A small bell (that fits through the neck of the flask).
 3. A rubber stopper and short piece of iron wire.
 4. A Bunsen or propane burner & stand, a cloth.

**Procedure:**

1. Attach the small bell to the wire and stick the other end in the rubber stopper. Adjust the length of the wire so that the bell will hang about in the center of the flask when closed off.
2. Close the flask off with the stopper and bell, shake the flask and let the students listen to the tinkle of the bell (a faint high note should still be detected).
3. Take the stopper off, pour about 20 ml of water in the flask, and heat it over the Bunsen or propane burner and stand until boiling.
4. Let the water boil for a minute or so and then shut the flame off, and immediately insert the stopper with the attached bell (hold the flask with the cloth to prevent burning of fingers).
5. Let the flask cool off for a minute, shake the flask again and try to detect the same faint high note of the bell.

Questions:

1. Why did the ring of the bell disappear after boiling water in the flask?
2. What is the purpose of boiling water in the flask?
3. If sound does not travel through a vacuum, could we hear rocket exhaust in outer space?
4. Why can sound not travel through a vacuum?

Explanation:

In order for human beings to hear a sound, sound waves or vibrations have to reach their ear drums, whether it is through a gas, a liquid or a solid. There has to be a *medium* in order for waves to travel from one place to the other. We hear sound and noises around us, because air is present everywhere. In the flask we created a partial vacuum. By boiling water, steam was produced and this pushed most of the air out of the flask. After the flask cooled, the steam condensed back into water and almost no air is left in the flask. This is why the bell could not be heard after the water has been boiling in the flask.

Any sound sources that are located in outer space (i.e. in a vacuum), are *not propagating any sound*. This is one of the reasons why we do not hear the tremendous sun explosions and the space travel sounds from the surface of the earth.

SOUND

MEDIUM OF TRAVEL

12.10. LISTEN TO THE POPPING BUBBLES

- Materials:
1. A can of fresh soda pop.
 2. A round-bottom flask or drinking glass.
 3. A tablet of Alka Seltzer (or other tablet which gives off gas bubbles when dissolved in water).



*dissolving
Alka Seltzer
in water-filled
flask*

Procedure:

1. Open a can of soda pop and place it immediately against your ear (or pour the soda in the flask, and place the flask against your ear). If soda pop is not available, do point 2.
2. Fill the flask or drinking glass with water and plunge a tablet of Alka Seltzer in it. Place the flask or glass immediately against your ear.
3. Listen to the popping bubbles.

Questions:

1. What kind of sounds did you hear in the can or flask?
2. Why couldn't you hear the popping bubbles through the air?
3. What do you do when you want to hear something better?
4. What medium did the sound travel through?
5. Would you think that sound travels easier through liquid or gas?

Explanation:

The source of sound in this case is formed by the bursting bubbles of carbon dioxide from the soda pop or the Alka Seltzer tablet. The bursting bubbles create waves in the liquid, which reach the can or glass container. This vibrates in turn and the air close to the ear carries the vibrations to the ear drum.

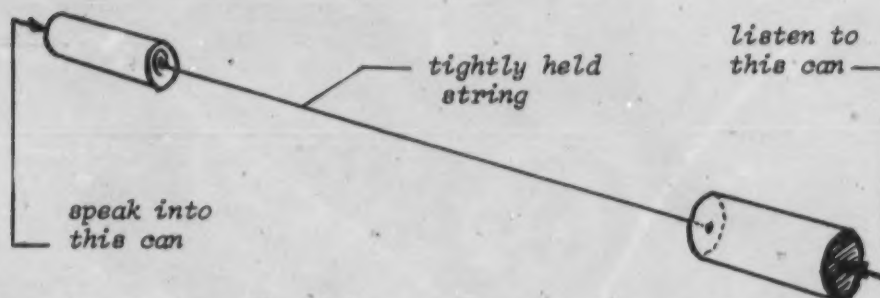
As soon as we bring the source of sound closer to the ear, we can hear it better. Like the ticking of a watch or someone's heartbeat, that we like to hear, we must bring the ear closer to the source. *Sound travels through liquids faster and easier compared to that in gases.* This is why the tapping of two rocks can be heard better under water than above water (try this in a swimming pool).

SOUND

MEDIUM OF TRAVEL

12.11. THE SODA-CAN TELEPHONE

- Materials:
1. Two empty soda pop cans.
 2. A string (same as length of the classroom).
 3. Nail & hammer, a can opener.

Procedure:

1. Cut one end of the two soda cans completely open with the can opener.
2. Punch a hole in the center of the other end with the nail and hammer.
3. Thread the string through the holes, such that the closed ends face each other and tie a large knot at the end of the string, so that it will not slip out of the hole.
4. Let two students stand at the far ends of the classroom, hold the cans keeping the string tight, and alternately speak softly and listen in the can (see sketch).

Questions:

1. How did the sound travel to the student's ear?
2. What did speaking in the can do to the bottom of the can?
3. Why did the string have to be held tightly?
4. Would this set-up work if we had a solid pipe or bar instead of the string between the two cans?
5. Could a whisper be heard from one end of the classroom to the other end, through the 'telephone'? Through the air?

Explanation:

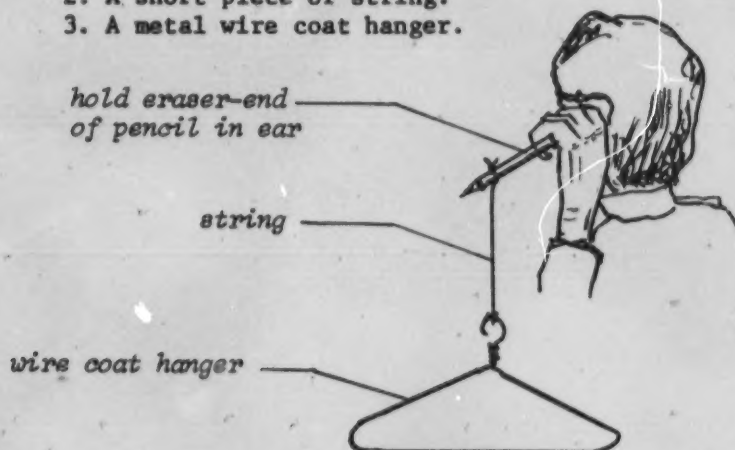
By talking into the can, the vibrations from the vocal chords make the air in the can vibrate. These vibrations are transferred to the bottom of the can, which in turn vibrates. The same vibrations are travelling along the string in *longitudinal waves*, making the bottom of the other can vibrate. The air in the receiving can is thus reproducing the exact vibrations of the first can, resulting in the same voice of the original sender. A whisper could not be heard through the air compared to a whisper through the 'telephone'. The waves travel through the solid string in the latter case, and it is much more facilitated. *Sound travels faster and easier through solids than through gases.*

SOUND

MEDIUM OF TRAVEL

12.12. THE COAT HANGER CHURCH BELL

- Materials:**
1. A pencil with eraser end.
 2. A short piece of string.
 3. A metal wire coat hanger.

**Procedure:**

1. Tie the string tightly to the pencil (opposite eraser end) and to the hook of the coat hanger.
2. Place the eraser end of the pencil in the ear and while holding it there, swing the coat hanger and let it hit a solid object (or hit the hanging coat hanger with another pencil).

Questions:

1. What do you hear with the ear in which the pencil is placed?
2. Why didn't you hear the coat hanger vibrations through the air?
3. What was the source of the sound?
4. Describe how the vibrations reached the ear from the source.
5. What other objects could we hang from the string for a source of sound?
6. What would you do to hear someone's heartbeat?
7. What other applications of this principle do you encounter in daily life?

Explanation:

The coat hanger hitting a solid object would vibrate and act as the source of the sound. The vibrations travel through the string and the pencil to the ear drum. As the string and pencil are solids, it is much easier for the sound waves to travel through them than through the air. It is the vibrations of the pencil that are immediately transferred to the ear drum, that make the sound so audible.

Similarly, we place our ear against someone's chest, in order to hear his/her heartbeat. By placing our ear against the railroad tracks, we can hear a train approaching long before we can hear the train sounds through the air.

SOUND

LONGITUDINAL WAVES

12.13. THE RESONATING BAR

- Materials:
1. An aluminum solid bar or hollow pipe ($3/4"$ or 2 cm diameter and about 3' or 1 m long).
 2. A damp cloth.

Procedure:

1. Let the aluminum bar balance on your right hand, by holding it between forefinger and thumb in the middle of the bar.
2. Rub the lefthand side of the bar with the damp cloth, slowly and gripping the bar rather lightly (try this several times until a high pitched tone is produced).
3. If the rubbing does not succeed, tap the bar vertically on a hard surface or hit the end of the bar with a hard object.
4. Stop the vibration by holding the bar on either end of the center with the left hand.

Questions:

1. What did the rubbing of the bar do to it?
2. Why does the rubbing as well as the tapping produce the same tone in the bar?
3. Would hitting the bar on the side produce the same tone?
4. Why can the vibration be stopped on the side of the bar that was not rubbed or hit?

Explanation:

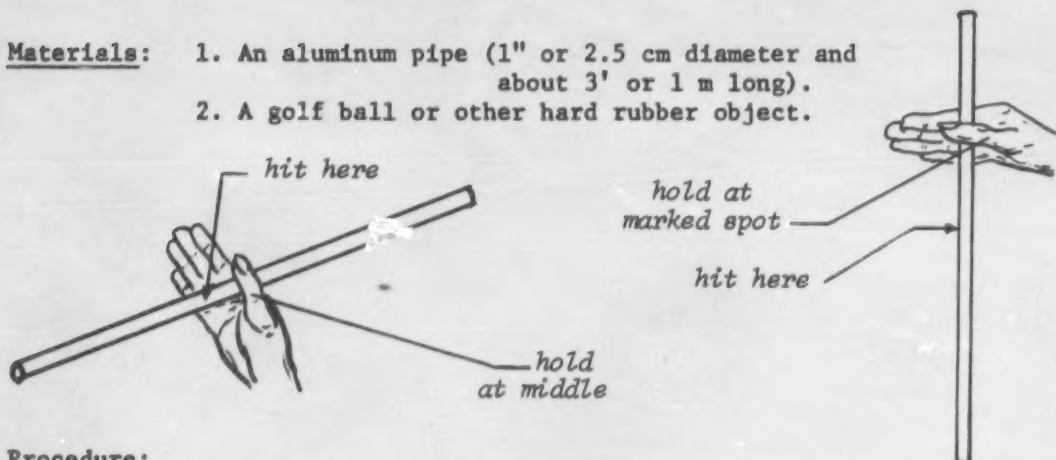
The rubbing with the damp cloth of the aluminum bar made the cloth slip and grab, slip and grab alternately, causing a *longitudinal* or *lengthwise* wave in the bar. The tapping at the end of the bar causes the same longitudinal wave, which will travel throughout the whole bar, not only on the side where the vibration originated. This is why the vibration can be stopped by holding even the end of the bar that was not rubbed. When the bar is hit on the side instead of at the end, a *transverse* wave is created, which has a much longer wavelength and thus a much lower tone or pitch compared to the longitudinal wave.

SOUND

STANDING WAVES

12.14. THE MULTIPLE TUNING PIPE

- Materials:**
1. An aluminum pipe (1" or 2.5 cm diameter and about 3' or 1 m long).
 2. A golf ball or other hard rubber object.

**Procedure:**

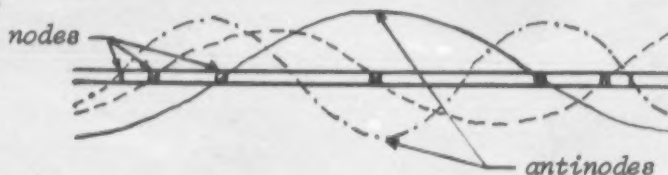
1. Let the pipe balance by holding it with the right hand between thumb and forefinger in the middle of the pipe.
2. Hit the pipe with the golf ball close to the middle of the pipe.
3. With a grease pencil or other marker, place marks on the pipe at places: 13, 25, 35, and 39 cm on each side away from the center (these are approximate distances: the correct spots may be found by holding the pipe at a spot and hitting it with the golf ball; the correct spot will be revealed by a pure resonating tone).
4. Hold the pipe between thumb and forefinger vertically at the marks and hit the pipe with the golf ball. What tones do you hear?

Questions:

1. Why did the pipe give different tones?
2. Did holding the pipe at different spots determine the tone?
3. Could the vibration continue by holding the pipe at more than one spot? More than two spots? Which of the spots?
4. Holding which of the spots would give the same tone?
5. Holding which of the spots on the pipe would give the highest pitch? The lowest pitch?

Explanation:

By holding the pipe at one spot and hitting it with the golf ball, we are getting a vibration in the pipe, resulting in a *standing wave*, detectable by a certain tone/pitch depending on where it is held. The spot 25 cm away from the center gives the lowest pitch, whereas the spots 13 and 39 cm from the center give the highest pitch. This is because of the shorter wavelength produced.



SOUND

RESONANCE & HARMONICS
BERNOULLI'S EFFECT12.15. THE TWIRLING BUGLE

Materials: 1. A corrugated plastic tube (a swimming pool drain hose or vacuum hose; about 6' or 1.5 m long, 4 cm diameter).

Procedure:

1. Hold the plastic tube in one hand at one end, and swing it above your head, first slowly, then faster and faster (different pitches will be heard--see Sketch A).
2. Tear a piece of paper up into a few small snippers and leave them in a heap on the edge of the table. Hold with one hand the stationary end of the tube above the snippers and with the other hand, swing the tube (the pieces of paper will be flying all over--see Sketch B).

Questions:

1. What made or produced the sound?
2. Why did we get different pitches by twirling the tube faster?
3. Why did the note skip in pitch; what is the next higher pitch called?
4. Which way is the air flowing in the tube?

Explanation:

The air flows from the stationary end to the circling end, because the air flowing past the moving end of the tube reduces the air pressure (*Principle of Bernoulli*--see chapter on flowing air). As the air flows along the corrugations of the tube, it starts to oscillate. The corrugations determine the frequency of the oscillations and thus the tone. The faster the air flows through the tube, the easier the *higher frequency harmonics* are excited, thus producing the higher harmonic tones.

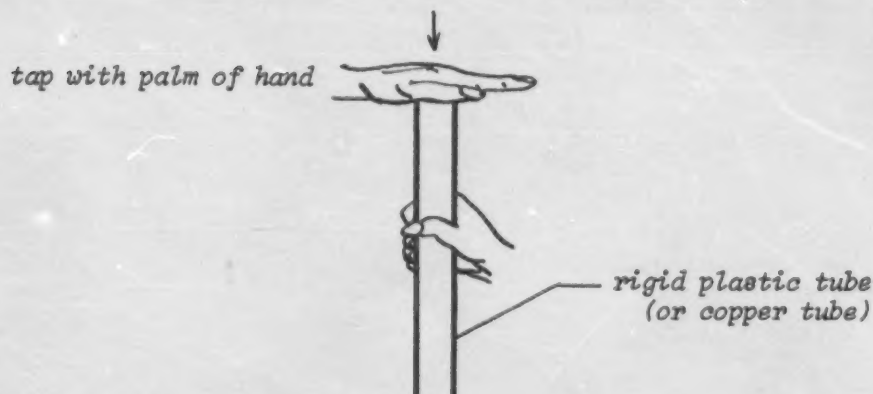
The pitch is also determined by the length of the twirling tube. The shorter the tube the higher the pitch. With a little practice in slowing down and speeding up the twirling, the sound of a bugle can be easily imitated.

SOUND

WAVE MOTION

12.16. THE TWO-NOTE TUBE

Materials: 1. A length of rigid plastic or copper tubing (2½" or 8 cm diameter, 1½' or 50 cm long).

Procedure:

1. Hold the tube with your right hand vertically and tap the top end with your flat left palm (hold the palm against the tube): a certain tone is produced.
2. Now tap the top end of the tube with the flat of your left hand palm and release the contact with the tube immediately after the tap; in other words: move your hand immediately away from the tube (it is like tapping the tube very lightly): another note is produced.
3. Keep alternating the two kinds of taps and let the students try to distinguish the two notes.

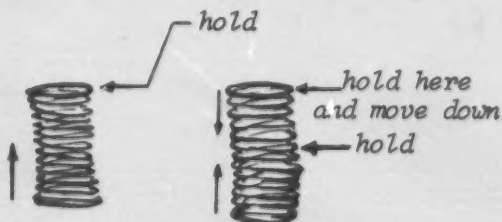
Questions:

1. How was the tone in the tube produced?
2. Which of the two tones produced had a higher pitch?
3. How are the two tones or pitches related to each other?
4. What type of waves did we create with the two kinds of taps?

Explanation:

By tapping the tube at the top end, a vibration of the air within the tube was created, producing a tone. When the palm is kept against the end of the tube, the wave is occurring in a tube with a *closed* or *fixed* end, producing a low tone. When the palm is tapped against the tube only lightly, the wave occurs in a tube with *open* ends, producing a tone an octave higher.

This can be illustrated by holding a short slinky vertically at the top only (closed end wave), or in the middle and moving the top faster (open end wave - see sketch on the right).

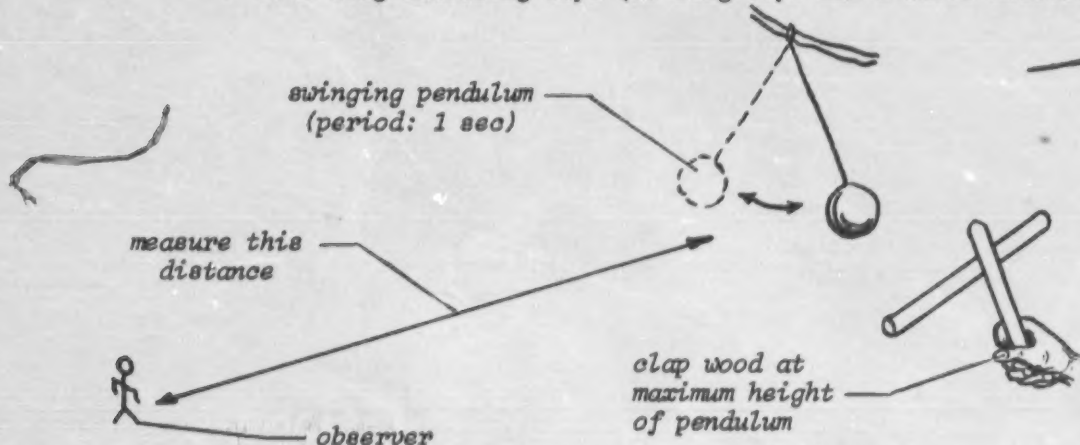


SOUND

VELOCITY

12.17. MEASURE THE SPEED OF SOUND

- Materials:**
1. A bright colored ball and string.
 2. Two pieces of wood (to make a clapping sound).
 3. A long measuring tape (or long rope and a short measuring tape)

**Procedure:**

1. Make a pendulum from the bright colored ball and string, such that it swings a full period (back and forth) within one second (by adjusting the length of the string).
2. Take the class out to an open field (it should be 170-180 m long), attach the pendulum to a horizontal bar or tree branch and have one student clap the two pieces of wood together at the exact moment that the pendulum reaches the highest point of the swing.
3. Have another student stand next to the one clapping, to keep the pendulum bob swinging (by giving it a reinforcing push).
4. Once the clapping and swinging are synchronized, let the rest of the students walk back from the pendulum while observing the swing and listening to the clapping (soon the taps will get out of phase with the swings, and slowly get back in phase with the swings).
5. Stop moving away from the pendulum, as soon as the taps are synchronized again with the swings of the bob, and measure the distance from where you are now to the swinging pendulum.

Questions:

1. Why was there a lag created between the taps and the swings?
2. What made the taps become synchronized again with the swings?
3. How can we calculate the speed of sound from the data?

Explanation:

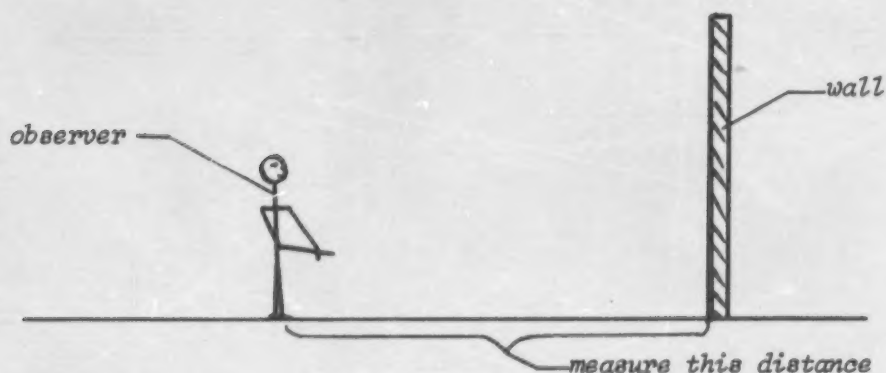
As the period of the swinging pendulum was one full second and the tapping of the wood was at each maximum height of the bob, the claps were $\frac{1}{2}$ second from each other. The distance from the observer to the pendulum (170 m) divided by the time ($\frac{1}{2}$ second) would be the speed or velocity of the travelling sound (340 m/sec).

SOUND

VELOCITY

12.18. THE ECHO SPEED CALCULATOR

- Materials:
1. Two pieces of wood (to make a clapping sound).
 2. An open space and a large vertical flat surface outdoors (such as a high wall of the school building).

Procedure:

1. Take the class outside to the side or back of the school building.
2. Start from about 20 meters from the wall (facing the wall) and move very slowly backwards while clapping with the wood pieces.
3. As soon as an echo of the clapping sound can be detected by someone, stand still and double check whether indeed an echo can be heard.
4. If indeed an echo can be heard, measure the distance from the observer to the wall.

Questions:

1. How can we calculate the speed of sound in this event?
2. Could we start the clapping by approaching the wall from further out?
3. Why do you think we cannot hear an echo when we are too close to the wall or vertical surface?

Explanation:

The minimum time interval that the human ear can detect between two claps is 0.1 second. When this interval between the clap and the echo is shorter than 0.1 second, no echo is heard. This is why no echo is heard when we stand too close to the wall. By moving slowly backwards away from the wall, an echo will be heard at a certain moment. At this moment the echo came back within 0.1 second, the distance between observer and the wall is measured (about 17 m), and the speed can be calculated from: distance sound travelled ($2 \times 17 \text{ m} = 34 \text{ m}$) divided by the time (0.1 sec) equals 340 m/sec.

When the speed of sound is already known, an approaching storm's distance may be estimated by counting the seconds between the lightning and the thunder, and multiplying this by the speed.

SECTION III

FORCES AND MOTION ON EARTH AND IN SPACE

This section consists of three chapters dealing with Newton's Laws of force and motion, applied on earth as well as in outer space. Some aspects of geology and astronomy are also discussed.

Chapter 13 deals specifically with the concept of gravity and the center of gravity of objects and systems, how torques can keep objects in balance, latent forces in rubber bands, the effect of sudden forces, simple machines, and the rate of falling objects.

Chapter 14 concentrates more on concepts and laws that can be applied to space science, like: inertia; Newton's First, Second, and Third Law; centripetal and centrifugal forces; conservation of momentum and plane of rotation; and weightlessness.

Chapter 15 deals with some aspects of geology and a few phenomena in astronomy. Erosion and weathering, volcanic action, and eclipses are some of the concepts dealt with.

In Science Learning



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CHAPTER 13

HOW DO FORCES AFFECT THINGS ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

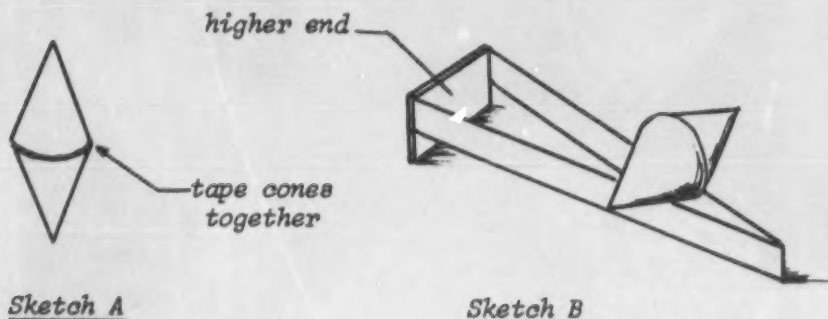
- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

- Gravity pulls objects toward the center of the earth.
- Falling objects fall at the same rate (in a vacuum).
- If the center of gravity of a system is located below its point of support, it is a stable system.
- Objects spin around their center of gravity.
- A torque consists of two forces working in opposite direction, which tend to spin or rotate an object.
- In a first class lever the fulcrum is between effort and resistance.
- In a second class lever the resistance is between fulcrum and effort.
- In a third class lever the effort is between the fulcrum and resistance.
- Inclined planes and pulleys, like first and second class levers, are meant to reduce the effort to lift heavy objects.

13.1. ROLLING UPHILL?

- Materials:
1. Strips of cardboard (about 3 cm wide).
 2. Paper cards and cello tape.

Procedure:

1. Make a cardboard ramp in the shape of a narrow V, and tape a wider cardboard strip to the open end of the V, so that this end will be about 2 cm higher (see Sketch B).
2. Construct two identical cones from the paper cards and tape them together (see Sketch A). Make sure that the surface of the double cone is smooth (especially where it is taped).
3. Place the double cone on the lower end of the V-shaped ramp and give it a starting push toward the higher end.

Questions:

1. How can an object roll uphill?
2. Does the double cone actually end up higher above the table?
3. Would a cylinder roll up the V-shaped ramp?
4. What force made the double cone roll toward the open end of the V?
5. What would a sphere do on the V-shaped ramp?

Explanation:

This demonstration invites students to be very observant. It gives the illusion of the double cone rolling uphill. The fact is that the double cone actually rolls downhill. It started higher above the table at the lower end of the V-shaped ramp and ends up lower above the table at the higher end of the ramp. It can be observed by fixing the eye on the tip of the double cone or actually measuring the distance between this point and the table top before and after the rolling.

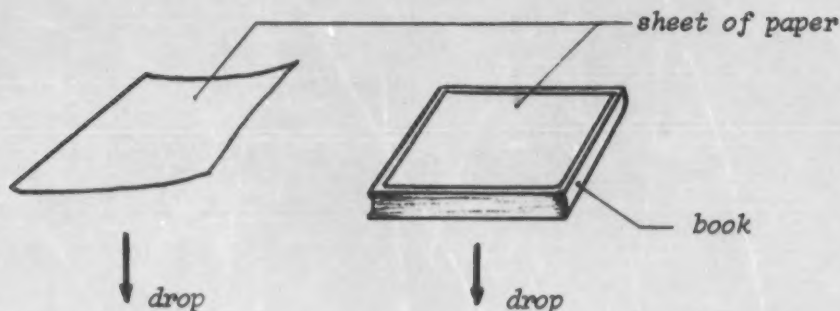
It is because of the shape of the double cone and that of the ramp, that the object's *center of gravity* slightly gets lowered when rolling from the tip to the open end of the V-shaped ramp. A cylindrical shaped object would not be able to roll "uphill" on this ramp. A spherical shaped object, like a ball for instance, would be able to roll towards the higher end of the ramp, but drops down much sooner between the legs of the V-shaped ramp.

FORCES

GRAVITY

13.2. WILL PAPER FALL LIKE A STONE?

- Materials:**
1. A hard cover book.
 2. A sheet of paper (the size of the book).

**Procedure:**

1. Drop a sheet of paper to the floor from arm's height (it will slowly fall, moving from side to side).
2. Drop a book separately (or beside the paper) to the floor from the same height (it will drop like a stone).
3. Now place the paper sheet on the book. Ask the students: "With the same gravity working on the paper and the book, will the sheet of paper fall at the same rate as the book?" (Anticipated answer: 'No').
4. Drop the book with the paper sheet on top of it (make sure that the paper's size is equal to or smaller than the book).

Questions:

1. Together why did the sheet of paper drop just as fast as the book?
2. Separately why did the sheet of paper drop slower than the book?
3. What would happen if the book were smaller than the sheet of paper and the two were dropped together?
4. What would happen if the sheet of paper were dropped in a vacuum tube?

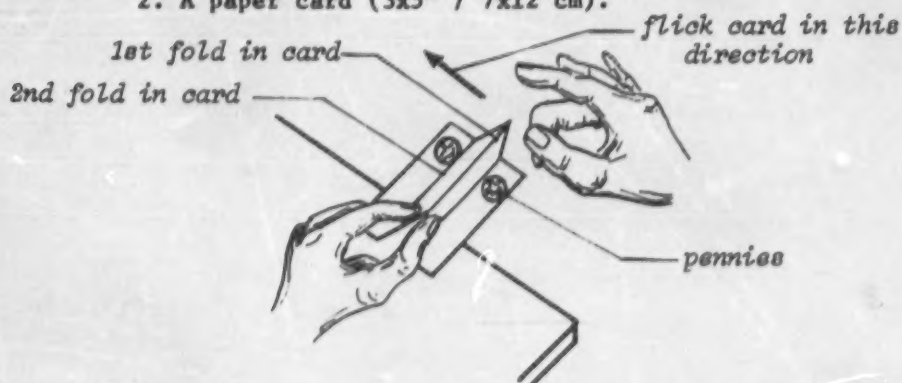
Explanation:

Dropping the sheet of paper to the floor by itself will make it move from side to side and descend slowly, because of the *air resistance*. The book is heavy enough to overcome the air friction and it drops in that short distance as if there were no resistance. Together, our intuition says that the paper should stay behind the book in falling to the floor, but they fall at the same rate, because under the paper there is no air and thus no resistance. It is as if the paper fell in a vacuum.

FORCES

GRAVITY
NEWTON'S SECOND LAW13.3. THE FALLING PENNIES

- Materials:**
1. Two pennies (or other coins).
 2. A paper card (3x5" / 7x12 cm).

Procedure:

1. Fold the paper card in half, then fold each side one third from the end outward.
2. Place the pennies on each side of the center ridge of the card and hold one end on the table edge (see Sketch).
3. Now flick the ridge of the card to the side with the middle finger of your right hand. This will fling one penny about 5 m away and at the exact same moment the other penny will drop straight to the floor.
4. Ask the students: "Which of the two falling pennies will hit the floor first?" (Anticipated answer: 'the straight falling one') Flick the card and listen to the click of the pennies hitting the floor.

Questions:

1. Did you hear one or two loud clicks of the falling pennies?
2. What would it mean if you heard only one click?
3. Does the direction of a falling object have any influence on the speed or rate of fall?
4. What was disregarded in this demonstration?
5. What can we conclude from this demonstration about the rate of fall of objects with different initial directions?

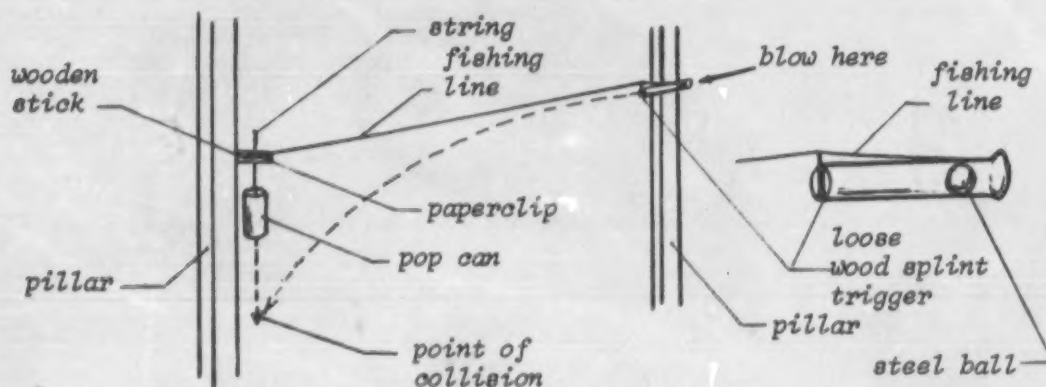
Explanation:

As both pennies were released at the same moment, the force of gravity started to work on the pennies at the same time. The downward component of the forces working on each of the pennies is therefore the same, and thus also the acceleration they obtain, resulting in reaching the floor in exactly the same time. This is why only one loud click (first click) is heard of the two pennies falling, regardless of the initial horizontal force imparted on one of them. When one of the pennies is replaced with a marble, the same one click will result, implying that all objects fall with the same rate (in a vacuum). In our case the air resistance was disregarded, because of the relatively short distance of fall.

FORCES

GRAVITY
NEWTON'S SECOND LAW13.4. HIT THE FALLING CAN

- Materials:**
1. An empty soda pop can.
 2. A test tube and steel ball (which fits in the tube).
 3. Fishing line (6-7 m long) & short piece of string.
 4. Two strong rigid heavy stands (two pillars about 4-5 m away from each other is ideal).
 5. A wooden stick, paperclip, splint, masking tape.

**Procedure:**

1. Break the bottom of the test tube by letting the steel ball roll down in it (a wide glass tubing could be used here instead).
2. Tape this tube horizontally about mouth-height to one of the pillars.
3. Punch a nail hole through the end of a 20 cm long wooden stick and get the fishing line through the hole.
4. Tie a paperclip to the end of the fishing line.
5. Tape the stick, slightly higher than the tube, to the other pillar.
6. Pull the fishing line rather tight from one pillar to the other (to where the tube is taped; the line should be slightly higher at the wooden stick end).
7. Tie a short string to the empty can and pinch the end of the string between the paperclip and the wooden stick. Set the trigger by placing a wood splint at the end of the tube (can should be held up when set, when wood splint falls the can should fall).
8. Place the steel ball in the tube and blow it hard in the direction of the hanging can (tube and can should be lined up).

Questions:

1. Why does the steel ball always hit the falling can?
2. Does it matter how hard we blow through the tube?
3. What force is pulling at falling objects?

Explanation:

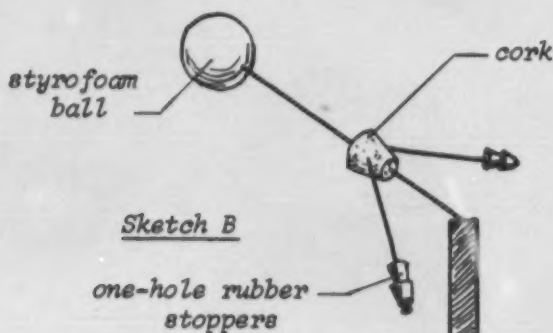
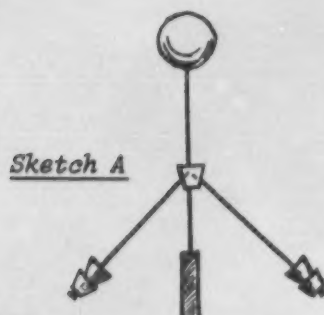
Disregarding the *air friction* in this case (actually in vacuum), *gravity* is pulling at the can and at the steel ball with the same force, thus no matter whether the ball had a horizontal component or not, they fall at the same rate and should meet each other in their path of fall.

FORCES

CENTER OF GRAVITY

13.5. THE BALANCING PINSMaterials:

1. Three knitting needles, or iron wires (30 cm).
2. Four one-hole rubber stoppers.
3. A cork (medium size), a styrofoam ball or cube.

Procedure:

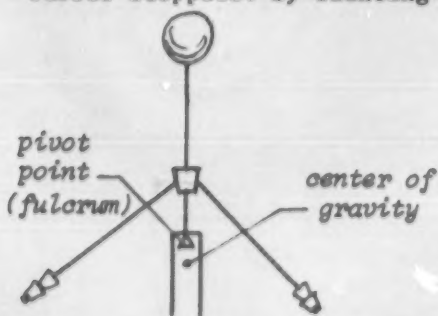
1. Stick one of the knitting needles, length wise, through the center of the cork, cut the head of the pin off, and stick the styrofoam ball to this end of the needle.
2. Let two of the stoppers fall in each of the remaining knitting needles through their hole.
3. Stick these pins rather slanted down into the side of the cork (Sketch A).
4. Let the whole system balance on your finger with the pin point as the pivot (use any protruding point as support).

Questions:

1. Why does the system of pins and stoppers stay up?
2. What is the purpose of the rubber stoppers?
3. What is the purpose of the styrofoam ball?
4. Where is the center of gravity of the system located? Without the pin with rubber stoppers? With the rubber stoppers?

Explanation:

The cork and styrofoam ball are very light in weight, compared to the rubber stoppers. By slanting the pins with the rubber stoppers down, the



center of gravity is lowered below the pivot point. Another way of lowering this center of gravity of the system is to shift the cork down. The lower the center of gravity of the system, the more stable the system is.

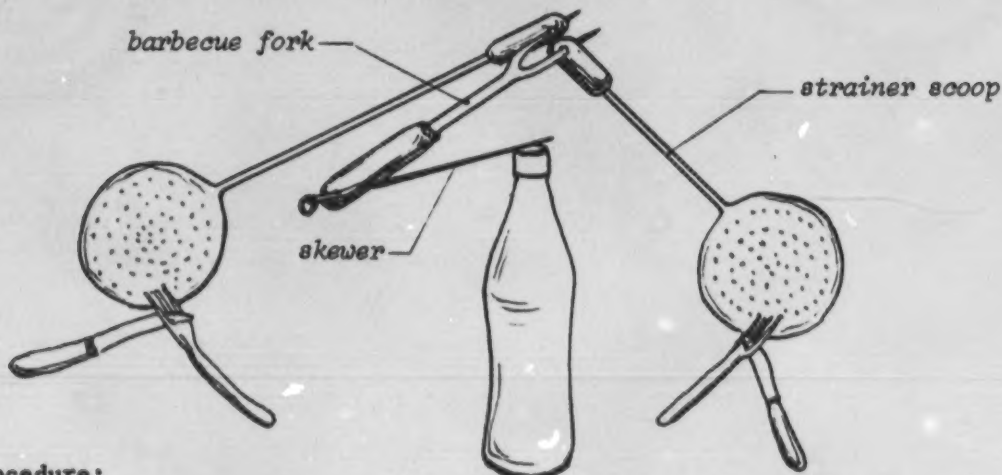
It is because of this principle that race cars are built as low as possible, so that in sharp turns they will hug the road and not roll over.

FORCES

CENTER OF GRAVITY

13.6. THE BALANCING ACT

- Materials:
1. A tall pop or wine bottle.
 2. Two strainer scoops, 2 forks, 2 knives.
 3. A barbecue fork and a metal skewer.

Procedure:

1. Attach the strainers through the handle holes to the barbecue fork, and push the skewer through the handle hole of the barbecue fork (see Sketch above).
2. While holding the system of utensils by the end of the barbecue fork, hang more weight on the strainers by pushing the fork teeth through the strainer holes and the knives through the fork teeth.
3. Balance the whole system of utensils now on top of the coke bottle by the end of the skewer.

Questions:

1. What makes the system stay balanced?
2. What is the purpose of the forks and knives?
3. Why doesn't the system stay balanced without the forks and knives?
4. What property is critical in deciding whether an object stays stable or unstable on a pivot point?
5. Where can we find applications of this principle?

Explanation:

The purpose of hanging the forks and knives on the strainers is to lower the center of gravity of the whole system, so that the system can stay stable on top of the pop bottle (pivot point). When the *center of mass* or *center of gravity* of a system is situated below the pivot point, the system is stable. *The lower the center of gravity of the system, the more stable the system is.*

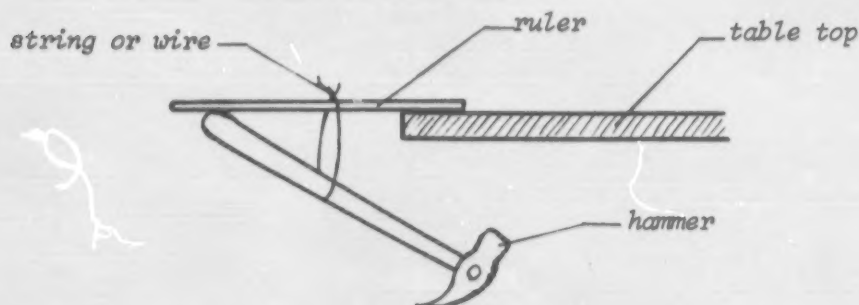
An application of this principle is found with rope dancers. When they walk the ropes they carry long heavy bent poles (probably weighted at the ends) in order to stabilize themselves.

FORCES

CENTER OF GRAVITY

13.7. HANG A HAMMER ON A LOOSE RULER

- Materials:
1. A hammer with a wooden handle.
 2. A wooden or plastic ruler.
 3. A short string or wire.

Procedure:

1. Take a flat wooden or plastic stick (the length of a ruler) and hang the hammer (with a wooden handle), with the iron part of it down, by means of a string.
2. Make a loop out of the string or wire (about 10 cm diameter), and slip it around the ruler and the handle of the hammer (let the end of the handle press against the ruler end).
3. Let the other end of the ruler hang from the edge of a table top.

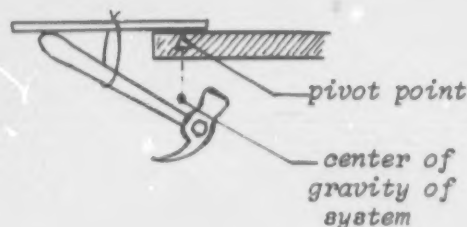
Questions:

1. What made the heavy hammer stay up at the edge of the table?
2. Why do we need a hammer with a wooden handle?
3. Can we consider the ruler really to be loose?
4. Where is the center of gravity of the hammer alone?
5. Where is the center of gravity of the whole system of ruler, string, and hammer?
6. What is the difference between a stable and labile system?

Explanation:

This demonstration can only be carried out when the hammer has a wooden handle, as the *center of gravity* is located in the iron part of the hammer. The plastic or wooden ruler and string do not add much to the weight of the system on the handle side. They make the position of the center of gravity of the whole system shift just a little towards the right and upwards.

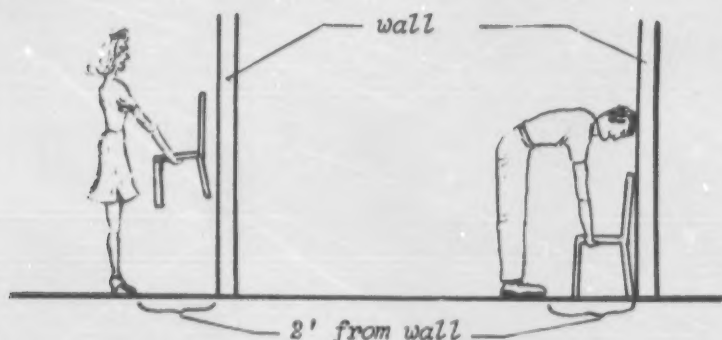
If this center of gravity is under the *pivot point* (point of support), it is a *stable* system. If the center of gravity is above the pivot point, it is *labile* and it falls.



FORCES

CENTER OF GRAVITY
HUMAN BODY13.8. ARE WOMEN STRONGER THAN MEN?

- Materials:**
1. A straight-back chair, some wall space.
 2. A few adult men and women (or teenage boys and girls).

**Procedure:**

1. Show what the people have to do:
 - a. Stand exactly two foot-lengths away from the wall (by measuring toe to heel off the wall with shoes on).
 - b. Bend over with a straight back (turning in the hips) and let your head lean against the wall (see Sketch).
 - c. Ask someone to hand you the straight-back chair (with the back against the wall).
 - d. Lift the chair while your head is still leaning against the wall.
 - e. With the chair in lifted position, try to straighten up (men cannot do this, but women can!)
2. Ask women and men to do the above alternatively (hand them the chair after they have stepped back from the wall).

Questions:

1. Why can girls or women straighten up and boys or men not?
2. Is the 'weaker' sex really stronger?
3. What is the difference in body build of male versus female?
4. Where is the center of gravity of the body located?
5. What is the average shoe or foot size of females versus males?

Explanation:

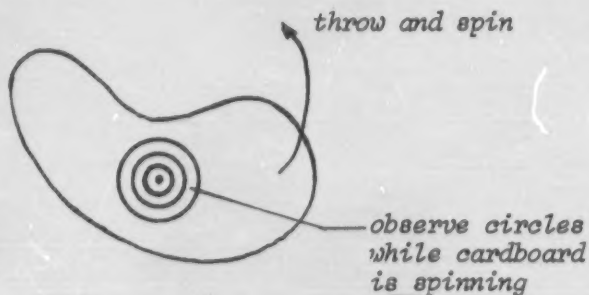
The result of this event has nothing to do with strength. It lies in the difference of the *location of the center of gravity* of the female compared to the male body, and the difference in foot size. The center of gravity of the female body is in the hip, while that of the male body is situated higher than the hip, because of the broader shoulders and narrower hips. The male foot size is generally larger than the female one, so he stands actually farther away from the wall than she does. When he bends over his center of gravity gets shifted beyond his toes, but with the female person this center of gravity stays above the foot, and straightening up poses no problem.

FORCES

CENTER OF GRAVITY

13.9. THE WOBBLING CIRCLES

- Materials:
1. A piece of cardboard, a pair of scissors.
 2. A drawing compass, a felt marker.

Procedure:

1. Cut the cardboard in a kidney shape.
2. Find the center of gravity of the cardboard shape by letting it balance on your finger and find the point where it balances: mark this spot.
3. Draw concentric circles around this spot with the compass and thicken the circles with the marker.
4. Draw exactly the same concentric circles on the reverse side of the cardboard, but around a spot 3 cm away from the center of gravity.
5. Have students now observe the following demonstration:
 - a. Let the cardboard piece spin vertically in the air, by flipping it upward holding the piece by one of its ends, (use wrist action when throwing) and catching it when it comes down.
 - b. Flip the board, so the students would see the other side (be inconspicuous in doing this) and spin the cardboard again.
 - c. Let students observe and follow the circles while the cardboard is spinning in the air.

Questions:

1. Why are the circles sometimes wobbling and sometimes steady?
2. How did I get the circles to wobble?
3. How can I find the center of gravity of the cardboard?
4. Around what point would an axe or hammer (with wooden handle) spin?

Explanation:

Steps 1 through 4 of the procedure should be done before the demonstration without having the students observe it. *All objects spin around their center of gravity.* By drawing the concentric circles around the center of gravity on one side of the cardboard, the circles stay steady when the board is spun. When the other side of the board is shown to the students, the circles wobble, because it is off center and the circles actually spin around a point outside the circle's center making a wobbling motion.

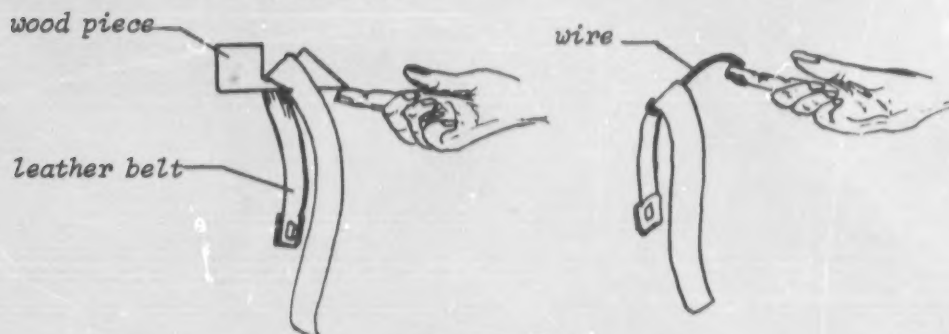
When an axe or hammer with a wooden handle is spun in the air, it will also spin around its center of gravity, which is very close to the iron part of the tool. This makes the handle seem to swing out much more than the metal part.

FORCES

TORQUES

13.10. THE FLOATING BELT HANGER

- Materials:**
1. A small piece of plywood cut in the shape pictured in sketch or a piece of coat hanger bent in an S shape.
 2. A leather belt.

**Procedure:**

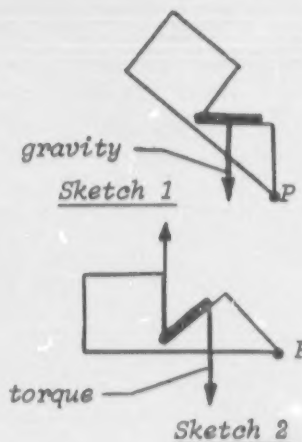
1. Ask students: "What will the wood piece do if I put it on my finger like this (see sketch but without belt) and let go of it?" (Anticipated answer: 'it will fall').
2. Let go of the wood piece or wire and let it fall.
3. Now hang a leather belt on the incline of the plywood piece or at the end of the iron wire (make sure that it balances).
4. Hold both ends of the belt in your right hand and pull at it--the belt is held up!

Questions:

1. Why doesn't the belt fall?
2. Which forces are working on the piece of wood?
3. In what position is the belt only exerting a downward force?
4. Can belts made of other materials also be hung on the 'hanger'?
5. How steep does the incline have to be for the belt to stay up?

Explanation:

At this position (Sketch 1) the belt is exerting only a downward force and no other. The incline is now a horizontal ridge. As soon as the shape is turned around point P in a clockwise direction, the belt hangs on an incline. Now it exerts more than a downward force. It now exerts a *torque* in counter clockwise direction. This means that *two equal but opposite forces that tend to rotate* are now working on the wood piece. The force which is exerting upward farther away from the pivot point P is the one that holds up the belt. The harder the pull downwards on the belt, the larger this torque becomes, and thus the larger the force upward.

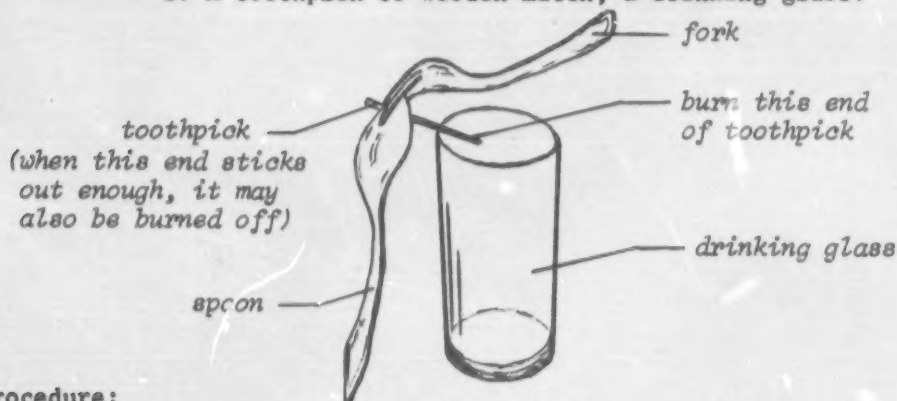


FORCES

TORQUES

13.11. THE FORK AND SPOON ACT

- Materials:
1. A fork and spoon (regular dinner silver).
 2. A toothpick or wooden match, a drinking glass.

Procedure:

1. Attach the spoon to the fork by pushing it in between the teeth.
2. Place a toothpick or wooden match between two of the fork's teeth and let the system balance from the toothpick resting on the rim of a drinking glass (see sketch).
3. Once the spoon and fork are in balance on the glass rim, dramatize by burning off the end of the toothpick or match.

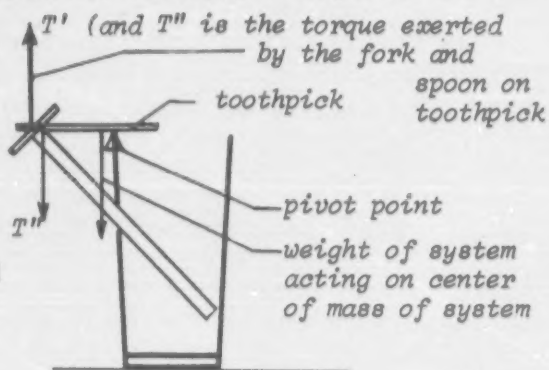
Questions:

1. What keeps the toothpick floating horizontally beyond the glass rim?
2. How far in or out can the toothpick protrude beyond the glass rim?
3. Why did the burning of the toothpick stop exactly at the fork or the glass rim?
4. What forces are working on the toothpick?
5. What other objects could be used in place of the toothpick?

Explanation:

The spoon and fork are hanging almost on their sides from the toothpick and this is the reason why they are actually exerting a torque on the toothpick (see sketch on right).

The burning of the pick stops exactly at the glass rim, because the heat of the flame is suddenly absorbed by the glass, and the temperature drops below the wood's *kindling point*. When the toothpick is protruding on both ends, it may be burned on both ends. The flame at the fork end will be extinguished for the same reason (the heat of the flame will be absorbed by the metal of the fork).

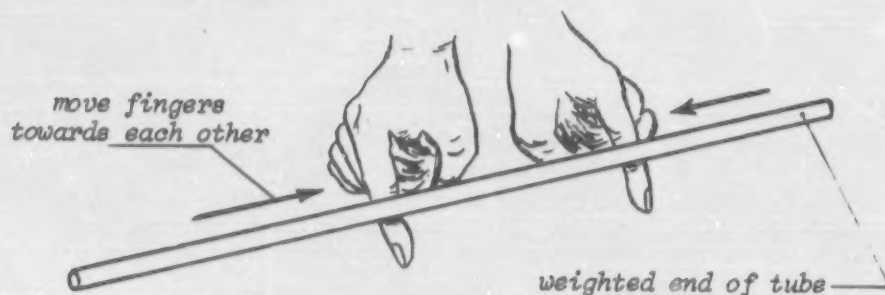


FORCES

TORQUES

13.12. THE WEIGHTED PIPE

Materials: 1. A 1 m long water pipe (weighted at one end with lead).

Procedure:

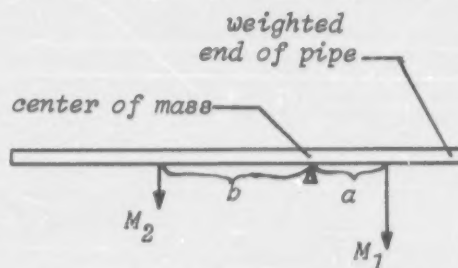
1. Take the water pipe and stuff one end with empty toothpaste tubes (do not show this to the students).
2. Place the weighted tube on your two stretched out forefingers at the far ends of the tube.
3. Move your hands slowly towards each other and ask: "Where will my fingers meet?" (they will not meet in the center of the pipe).

Questions:

1. Why did the fingers not meet at the center of the tube?
2. Holding the tube at the center of mass, which end of the tube is heavier? The short end or the long end?
3. Where are the actual forces working on the pipe in relation to the pivot point, which is the center of mass of the whole pipe?
4. Where would the fingers end up if the pipe were not weighted?

Explanation:

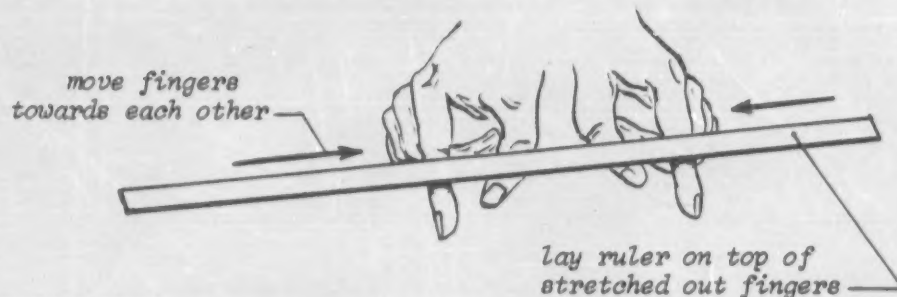
Under the weighted pipe, the sliding fingers will end up under the center of mass of the whole pipe, which is off center, more shifted towards the heavy end. The short end of the pipe is heavier than the long end, yet they are in balance, because the larger force (M_1) has a shorter arm (a) and the smaller force (M_2) has a longer arm (b) in relation to the pivot point (center of mass-- see sketch on right). When the object is in equilibrium, all clockwise couples ($M_1 \times a$) equal the sum of all counter clockwise couples ($M_2 \times b$).



FORCES

CENTER OF GRAVITY
FRICTION & TORQUES13.13. THE GOLDEN MIDDLE

- Materials:
1. A meter stick (one for each pair of students).
 2. A weight (200 g) or rock.

Procedure:

1. Take the meter stick and place it in any position on your two stretched out forefingers.
2. Move the fingers towards each other: they always end up in the middle of the ruler.
3. Distribute the meter sticks to each pair of students and let them try to do the event themselves.
4. Place a weight or rock at 25 or 75 cm from the end, and let students bring their fingers together. Where do they end up?

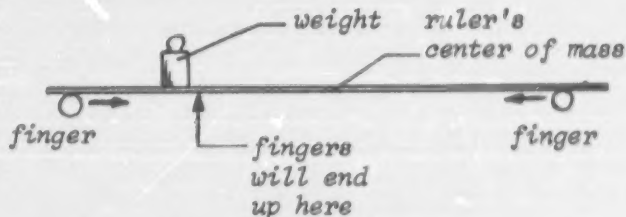
Questions:

1. Why do the fingers always end up in the middle of the ruler?
2. Does it matter where the two fingers are placed initially?
3. Which finger moves more: the one closer or farther from the center?
4. What is keeping the finger closer to the middle from moving?
5. Where is the center of gravity of the ruler (without the weight)?
6. Between which finger and the ruler is there more friction: the one closer or farther from the middle?

Explanation:

Since the *center of gravity* (*center of mass*) of the ruler is in the middle of the ruler, it presses more on the finger which is closest to the middle. This causes a greater *friction* for this finger when moving it. So the finger which is farther from the middle would move first, until both fingers are the same distance from the middle, then both fingers move at the same rate towards the middle.

If a weight was placed at one end of the ruler, we will notice that the fingers will end up very close to the mass or weight, or rock placed on the ruler. This is because the center of gravity of the whole system (stick + weight) is shifted.

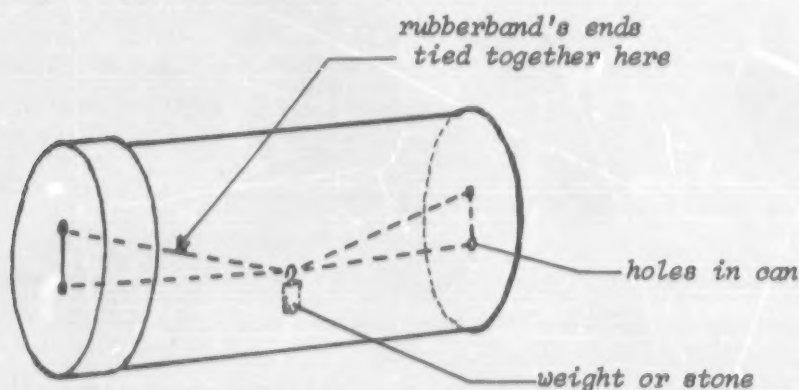


FORCES

LATENT FORCES

13.14. THE MAGIC COME-PACK CAN

- Materials:
1. A tin can with an opaque lid.
 2. A thick, long rubberband and a short piece of string.
 3. A weight or stone.

Procedure:

1. Make two small holes in the bottom and also in the lid of the can about 2 cm apart.
2. Cut the rubberband and push it through the holes, and tie the loose ends together inside the can (see sketch).
3. Tie a short piece of string around the weight or stone and tie the other end of the string to the center of the rubberband (do not let the weight or stone drag on the side of the can).
4. Place the lid back on the can, and you are now ready for the demonstration: Roll the can on a horizontal plane (the table top) and it comes rolling back!
5. Wind the rubberband up first, and let it roll uphill on an inclined plane.

Questions:

1. Why did the can roll back (or roll uphill)?
2. What is the purpose of the rubberband?
3. What else is inside the can besides the rubberband?
4. How is the construction inside the can?

Explanation:

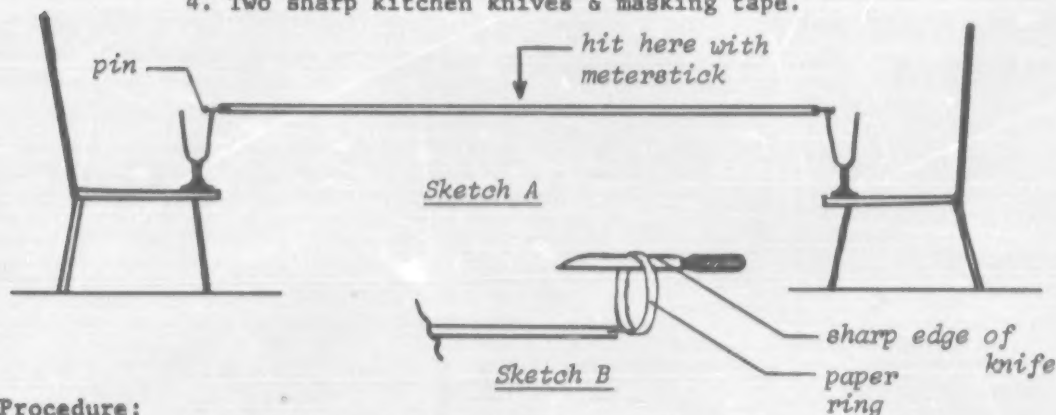
The purpose of the rubberband is to provide the rolling-back action. The weight or stone holds the rubberband stationary in the center of the can, so that when the can rolls, the rubberband twists itself, building up a *latent force* inside it, and when it untwists itself the cylinder rolls back. It can even roll up not too steep an incline.

This demonstration is quite suitable for a *black box* activity, where students have to figure out what is inside the can that makes it move, without looking inside it (exercise on inferring).

FORCES

CENTER OF GRAVITY
SUDDEN STRESSES13.15. THE INCREDIBLE STICK

- Materials:
1. A thin and long pine stick (2m x 1cm x $\frac{1}{2}$ cm).
 2. Two wine glasses or small beakers.
 3. Two pins, a thick meter stick (or other strong stick).
 4. Two sharp kitchen knives & masking tape.

Procedure:

1. Push the pins into each end of the wooden stick.
2. Place the wine glasses or the beakers each on the edge of a chair or table, space them 2m apart, and let the long wooden stick rest on the rim of the glasses suspended from the pins (see Sketch A).
3. An alternative would be to suspend the wooden stick on two thin paper rings hung on the sharp edge of the kitchen knives (taped against the back of two straight-back chairs--see Sketch B).
4. Hold the strong meter stick like an axe over your head and give the long horizontal stick a sharp blow in the center of its length.

Questions:

1. Why did the beakers not break or fall? (for alternative A)
2. Why did the paper rings not tear? (for alternative B)
3. Was the force exerted on the center of the stick large or small?
4. How did the two broken pieces of wood move when they were hit?
5. Around what point do rotating objects move?

Explanation:

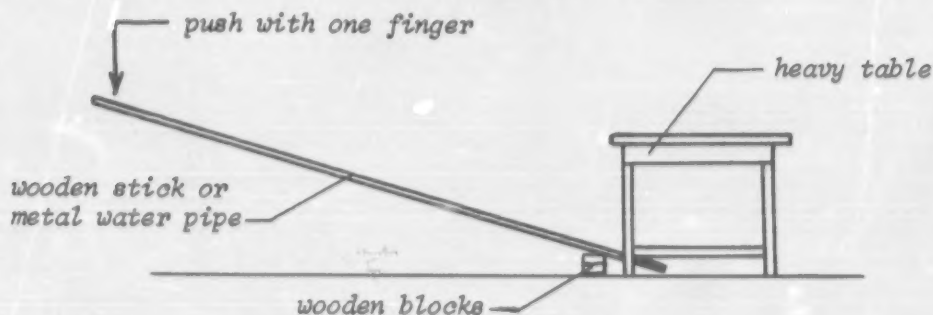
The force of the blow was so sudden in the center of the wooden stick, that it broke before the force could be exerted on the paper rings or on the glass rims. The descending cudgel hits the center of the stick with such a great and sudden force that the center part descends and breaks. The two broken pieces are actually being suddenly rotated, one in a clockwise and the other in a counter clockwise direction. As *rotating objects rotate around their center of gravity*, the far ends of the long stick actually move slightly upwards, as the two pieces start rotating. The result of the blow is spectacular: The center of the stick falls victim to the *sudden influx of energy*, whereas the ends remain pretty well stationary or even move slightly upwards.

FORCES

FIRST CLASS LEVERS

13.16. TILT A HEAVY LOAD WITH ONE FINGER

- Materials:
1. A long wooden stick (shovel handle) or an iron water pipe (3-4 m).
 2. Two or three small wooden blocks.
 3. A heavy piece of furniture.

Procedure:

1. Have students try to lift one side of the heavy piece of furniture to give them an idea of its weight.
2. Place the two or three wooden blocks close to the side of the table to be tilted, place the end of the long stick under the table rung and use the blocks as a fulcrum for the lever (see Sketch).
3. Now push the long end of the stick with one finger down (as a heavy load, a desk or table, or a chair with a student sitting on it, may be used; make sure that a rung or horizontal bar is present, close to the bottom of the load to be lifted, to hook the lever on).

Questions:

1. What type or class of lever are we dealing with?
2. What functions as the resistance in this case?
3. What were the effort and the fulcrum in this lever?
4. What other examples can you name that are based on this class lever?

Explanation:

This *lever of the first class* has the *pivot or fulcrum* in between the *effort* and the *resistance*. The latter one being the heavy load (table, desk, or chair with someone seated on it) and the effort being the finger pushing on the long end of the lever, and the blocks of wood serve as the pivot or fulcrum.

Other examples applying the first class lever are: a pair of pliers, a pair of scissors, wire and chain cutters, most car jacks, teeter totters, crow bars, etc.

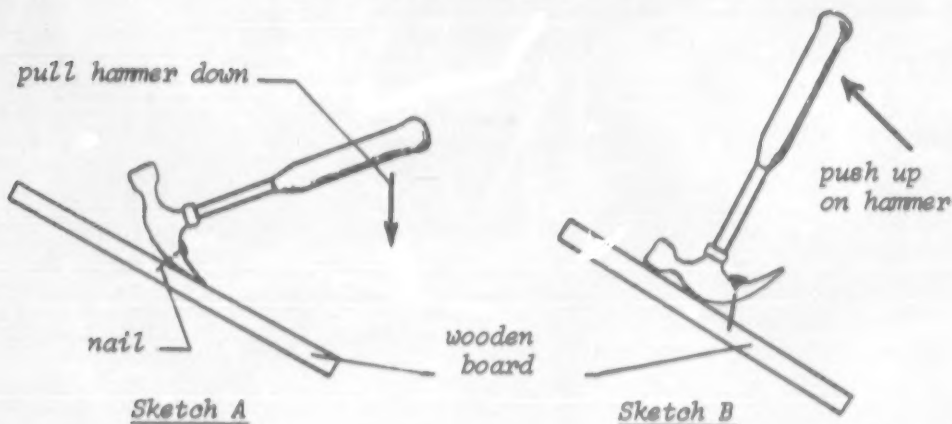


FORCES

SECOND CLASS LEVERS

13.17. IS THE HAMMER A LEVER?

- Materials:
1. A hammer (which can be used to pull nails out).
 2. A wooden board and small common nails.

Procedure:

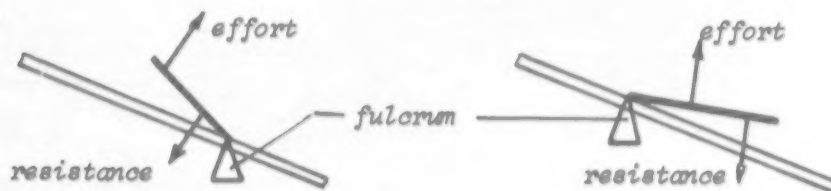
1. Hammer a couple of nails into the wooden board (half way) and pull one nail out by pulling down on the hammer (see Sketch A).
2. Pull the other nail out by pushing up on the hammer (see Sketch B).
3. Ask students the questions listed.

Questions:

1. Which of the two methods of taking out the nails was an application of the second class lever?
2. What class lever was the other method applying?
3. Where is the fulcrum, effort and resistance located in method A? Where are these in method B?
4. What other examples can you name that apply the second class lever?

Explanation:

The best way to clarify where the forces are at work with the hammer pulling the nail, is to draw a sketch of both methods and the relationships and location of the forces and fulcrum.



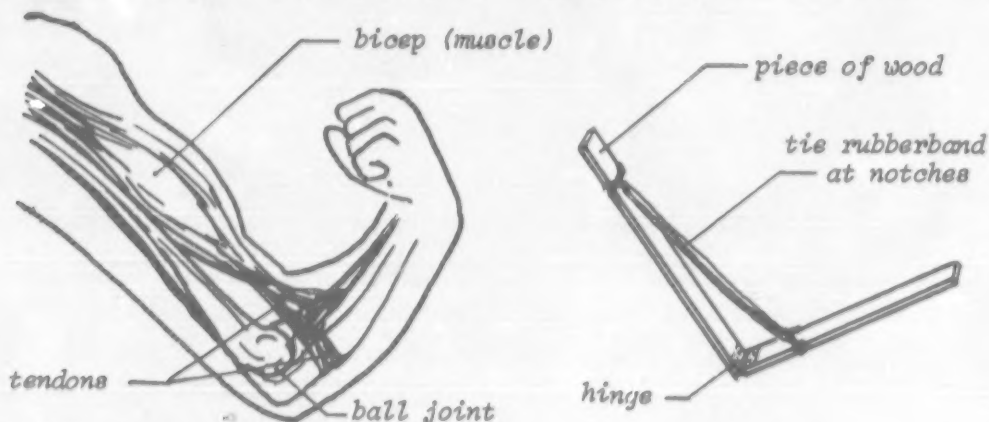
Method A is applying the second class and method B the third class lever. Other examples of second class lever applications are: the wheelbarrow, crow bar, nut crackers, paper cutters, two-hole punchers.

FORCES

THIRD CLASS LEVERS

13.18. THE THIRD CLASS BICEP

- Materials:
1. Two pieces of wood (or two rulers).
 2. A small hinge (or masking tape), & thick rubberband.

Procedure:

1. Attach the two pieces of wood together by means of the hinge (or tape the two rulers loosely together).
2. Cut grooves for the rubberband close to the free end of one arm and close to the hinged end of the other arm.
3. Tie the rubberband around each arm where the grooves are. You are now ready to show the bicep action.

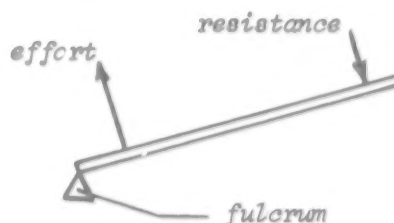
Questions:

1. What class lever is the movement of the lower arm based on?
2. What does the rubberband simulate?
3. Locate the fulcrum, effort, and resistance in this arm lever.
4. Are other muscles in our body and the movement of the body parts based on the same class of levers?
5. What other examples can you name that are applying the third class lever in our daily life?

Explanation:

The bicep is the *effort* in a third class lever when moving the lower arm upwards. This is illustrated by the rubberband when it is contracting. The hinge is the joint or *fulcrum* between the lower and upper arm, and the *resistance* is the weight of the arm alone or any additional weight that the arm is lifting (see sketch on the right).

Other third class levers in our daily life are: a pair of tweezers, ice tongs, moving a hockey stick, using a shovel, broom, or rake, etc.

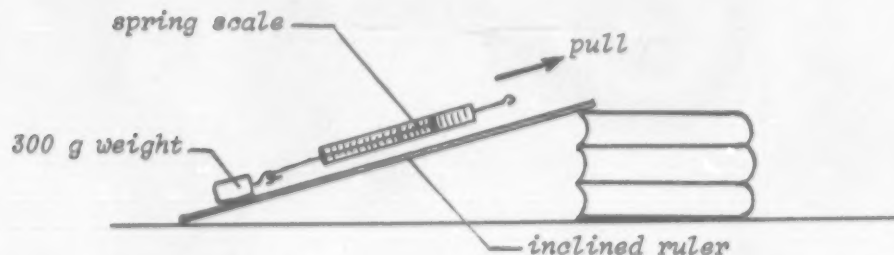


FORCES

INCLINED PLANE

13.19. WHICH ONE IS HEAVIER?

- Materials:
1. A 200 g and a 300 g weight.
 2. A spring scale (500 g maximum).
 3. A 30 cm plastic ruler & a stack of books.

Procedure:

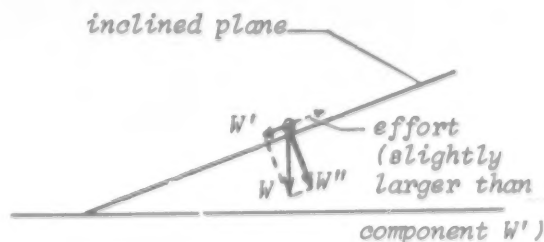
1. Place three or four textbooks on top of each other.
2. Place the two weights next to the stack of books and tell students that your task is to move the weights up on top of the stack.
3. Ask students: "Which one will take more effort to move?" Place the ruler on an incline (one end on top of the books and the other end on the table), and pull the 300 g weight over the ruler up on the stack of books with the spring scale (read the effort off this scale while moving the load).

Questions:

1. How much effort did it take to move the 200 g weight straight up?
2. How much effort did it take to move the 300 g weight over the incline on top of the stack?
3. Why was the effort much less than 300 g on the incline?
4. How are the force components working on the incline?
5. What are other applications of the inclined plane?

Explanation:

It takes much less effort than the full weight to move the 300 g mass over the inclined ruler, as the incline component force (W') is much smaller. The less steep the slope of the incline, the smaller the effort. The weight on the incline (W) may be decomposed into a component perpendicular to the incline (W'') and one along the incline (W'). The effort would be slightly larger than W' (to overcome friction). Other applications are: the screw, the wedge, axe, chisel, etc.

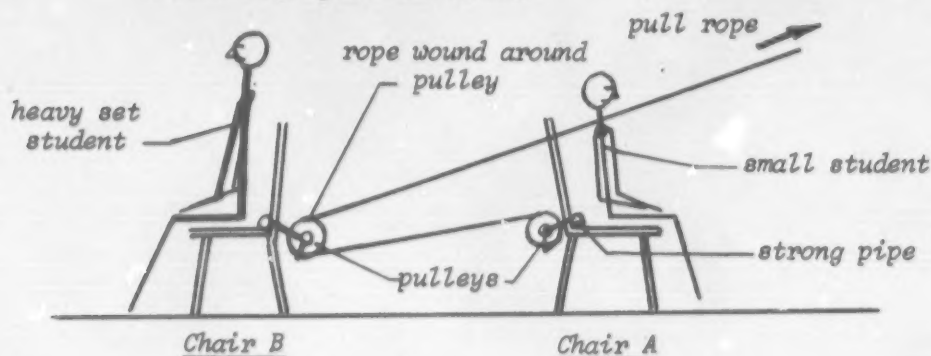


FORCES

PULLEYS

13.20. WHICH ONE WILL BE MOVED?

- Materials:
1. Two clothesline pulleys.
 2. A sturdy rope & two strong sticks or pipes (50 cm).
 3. Two straight-back chairs.

Procedure:

1. Attach each pulley to the center of each of the rods or pipes with a short piece of rope, and slip the rod between the seat and back of each chair, so that it catches on the frame when the pulley is pulled backwards.
2. Tie the end of a long rope to the other hanger of one pulley (see sketch Chair A), and thread the other end of the rope around the pulley of Chair B, and hold the end of the rope on the side of Chair A.
3. Have a tiny built student sit on Chair A and a heavy set student on Chair B, and ask: "Which of the two will be moved when I pull on the rope?" (ant. ans: A). Pull and observe Chair B move!

Questions:

1. Which of the two students is heavier?
2. Why did Chair B, the heavier one, move and not Chair A?
3. Which of the chairs would move if the students were of equal weight?
4. Which one would move if the rope were also wound around pulley A, and the rope end attached to the floor?

Explanation:

There is only one rope pulling at Chair A and two ropes pulling at Chair B. *The force or tension in each of the ropes is equal* and thus the force pulling at Chair B is twice as large as that at Chair A. This is why even the heavier student sitting on Chair B is moving. If the rope were also wound around pulley A, Chair A would be moved (with the lighter student--see Sketch B on the right).

Sketch ASketch B

CHAPTER 14

WHAT DO WE LEARN WHEN DEALING WITH SPACE SCIENCE ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

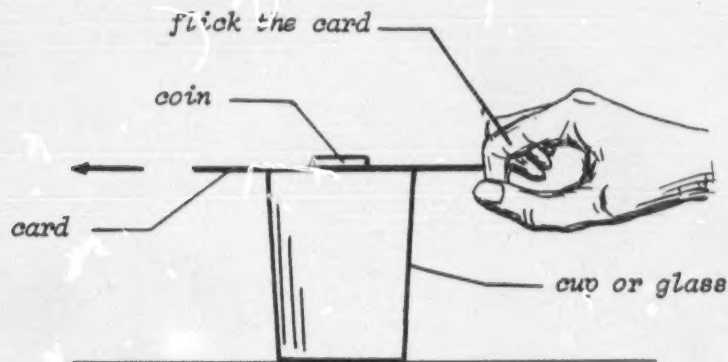
- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

- Inertia is the tendency of still objects to stay at rest.
- The larger the mass of an object, the more inert it is.
- Newton's First Law: a. An object at rest tends to stay at rest.
b. An object in motion tends to stay in linear motion.
- Newton's Second Law: The acceleration of a moving object is directly proportional to the force exerted on it and inversely proportional to its mass ($F = m \times a$).
- Newton's Third Law: When a body exerts a force upon a second body, an equal and opposite force is exerted upon the first body: for every action there is an equal and opposite reaction.
- When an object is swung in a circular motion, there is an inward centripetal force working on the string.
- The momentum of an object is equal to the product of its mass and the velocity it has.
- When a moving object collides with another object, its momentum is conserved ($m_1v_1 = m_2v_2$).
- The angular momentum of an object is unchanged unless an external torque acts on it (conservation of angular momentum).

14.1. PUT THE COIN IN THE CUP

- Materials:
1. A paper card and a coin.
 2. A cup or drinking glass.

Procedure:

1. Cover the cup with the paper card and put the coin on top of the card.
2. Now ask the students: "How can I get the coin in the cup without lifting the card?"
3. After hearing all the different suggestions, flick the card with your forefinger in a horizontal direction.

Questions:

1. Why does the coin drop in the cup when the card is flicked away?
2. What held the coin back when the card was moved?
3. What happens to the coin if the card is pulled slowly?
4. Could we pull the card away rather than pushing it away?
5. Where do we see this event applied in daily life?

Explanation:

This event is based on the common characteristic that all objects have and that is *inertia*. The coin lies *inert* on the card and by pushing the card suddenly away, the coin slides over the card and drops in the cup. The more sudden the movement of the card, the easier the coin will stay at rest. If the card is pulled slowly away, the coin will move with it. When pulling at the card instead of flicking it, the pulling has to be carried out with a sudden motion as well.

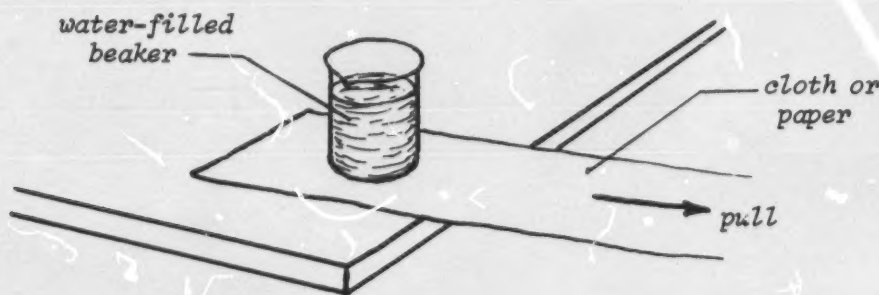
We find this event in our daily life when we stand in a city or school bus, which suddenly starts to move. The bus moves forward with an abrupt motion and the standing person falls backward, because he/she had the *inertia*, which is also called the tendency to stay at rest. The larger the mass of an object, the greater its *inertia*. The *inertia* of an object is directly proportional to its mass.

SPACE SCIENCE

INERTIA

14.2. PULL THE TABLECLOTH

- Materials:**
1. A large beaker (or other glass container with a smooth base).
 2. A long narrow cloth without seam (paper towel will do).

**Procedure:**

1. Fill the beaker with water and make sure that the outside of the beaker is bone dry.
2. Find a very smooth table top, wipe and dry it off, place the water-filled beaker close to the edge on top of the strip of paper.
3. Now pull at the paper strip, first slowly until the beaker comes to about 2 cm or so from the edge of the table, then pull with a sudden jerk (do not hesitate!).

Questions:

1. Why didn't the beaker fall off the table?
2. What made the beaker move closer toward the edge?
3. Why do we need a smooth table top for this demonstration?
4. What is the purpose of the water in the beaker?
5. What events in daily life make use of this principle?

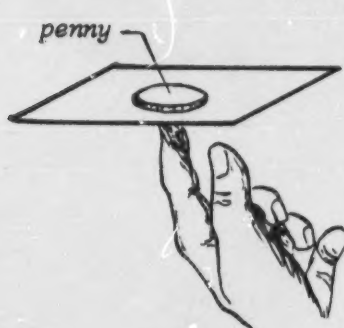
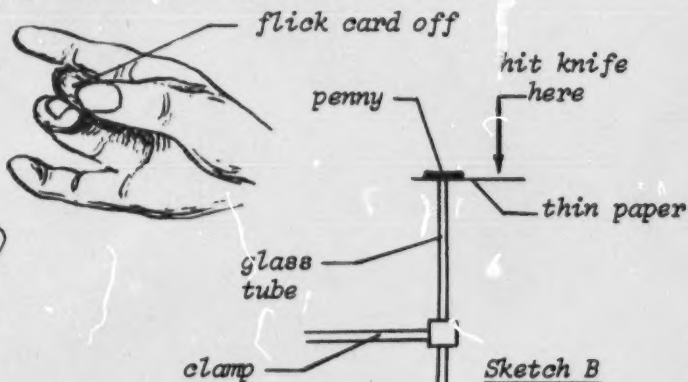
Explanation:

This demonstration can be made most dramatic by placing the beaker about 50 cm from the edge of the table at the start and then pulling it to about 2 cm from the edge. This shows the students that pulling the paper will pull the beaker with it. The slow pull gives enough friction between the paper and the beaker, so that the beaker stays on the paper. The water in the beaker makes it heavier, and *the heavier the object, the greater its inertia or its tendency to stay at rest*. This is why it works easier with the water in it. The table top and the bottom of the beaker need to be smooth and dry, so that a minimum of friction exists when the paper is pulled from under the beaker.

An application of this first part of Newton's First Law in daily life is encountered when we move gravel or other heavy material with a shovel from one place to another: we pull the shovel with a sudden move out from under the gravel or in under the pile of gravel.

14.3. THE IMMOVABLE PENNY

- Materials:**
1. A penny, paper card, and thin paper.
 2. A short glass tube, clamp and stand.
 3. A sharp long kitchen knife or hacksaw blade.

Sketch ASketch BProcedure:

1. Cut a 3 x 5" card in half, place the penny in the center on top of the card, and balance the card and penny on your left index finger tip (see Sketch A).
2. Flick the card off your finger with your right middle finger (do this horizontally in the plane of the card): penny stays on finger tip!
3. Clamp the glass tube vertically, place a short thin strip of thin writing paper on the top end of the glass tube, weighted by the penny (see Sketch B).
4. Hit the protruding end of the paper with the sharp edge of the kitchen knife or saw blade: penny stays on glass tube!

Questions:

1. What made the penny stay on the finger or on the glass tube?
2. Will the slow removal of the card or the paper have the same effect?
3. What other objects can we use instead of the penny?
4. What implications do you see when doing this on the moon?

Explanation:

The removal of the card or paper has to be done with a quick action otherwise the friction factor will play a role. A slower movement of the card or paper will bring the coin with it. Also the flicking of the card has to be carried out, such that the card will slide off horizontally without tipping the coin.

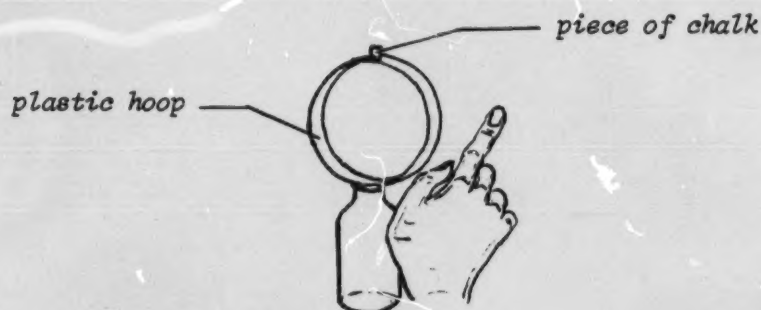
In hitting the protruding paper with the sharp edge of the knife, the paper is folded up exactly where the knife hits it, and the sharp edge grabs on to the paper and pulls it away.

Other objects that can be used instead of the penny are: other coins, washers, etc. On the moon this event can be done much easier, as the mass stays the same but the weight is less, and thus the friction is less.

SPACE SCIENCE

DIRECTION OF FORCE
INERTIA14.4. GET THE CHALK IN THE BOTTLE

- Materials:**
1. A flexible plastic hoop (cut from a polyethylene container).
 2. A bottle with a narrow neck.
 3. A small piece of chalk.

**Procedure:**

1. Cut a narrow (1 cm wide) hoop from a flexible polyethylene container.
2. Place it on the mouth of the bottle and center a small piece of chalk vertically over the opening of the bottle.
3. Flick the hoop with your finger from under the chalk by hitting the hoop on the inside (but holding the finger on the outside of the hoop before the flicking itself).
4. Let students observe carefully where you hit the hoop without telling them what you are doing.
5. Let students try to get the chalk in the bottle (those that know where to hit the hoop will be able to do it, others will not).

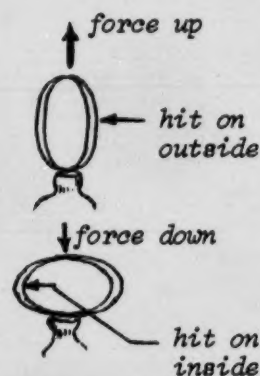
Questions:

1. Did you observe where the hoop was hit with the finger?
2. Why does the chalk fly off if the hoop is hit on the outside?
3. What force acts on the chalk when the hoop is hit on the outside?
4. What will the hoop do if hit on the outside or on the inside?

Explanation:

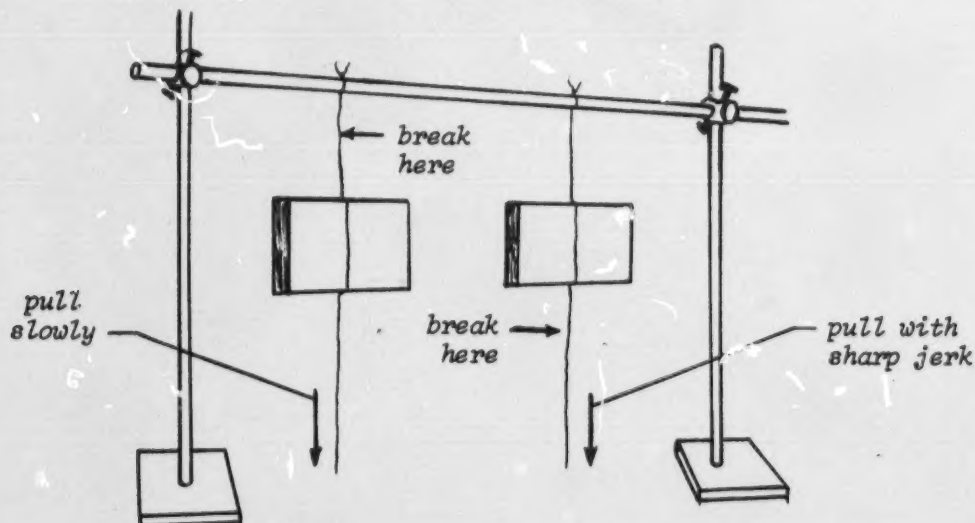
The demonstration can be used to focus students' attention on careful and accurate observation skills. Without telling them where the hoop is hit, they should be able to find out for themselves.

When the hoop is hit on the inside, it flattens and slips out under the chalk. When it is hit on the outside, the force is upwards, and the chalk gets pushed up. (see sketches on the right).



14.5. BREAK THE STRING WHEREVER YOU WANT

- Materials:**
1. Two paperback pocket books (same thickness).
 2. A horizontal stand and sewing thread.

**Procedure:**

1. Tie threads around each of the books, such that a loose end comes out from each side of the book.
2. Tie one end of the thread around the horizontal stand and let both books hang side by side (see sketch).
3. Now ask the students: "Where do you want me to break the thread of book No. 1? Above or below the book?"
If they answer: 'above the book', pull slowly at the thread.
4. For book No. 2, pull the thread with a short jerk: thread will break below the book!

Questions:

1. Do you see any difference in the way the thread was pulled?
2. Why does a slow pull at the thread break it above the book?
3. Why does a sharp jerk break the thread below the book?
4. Which of the two breaks makes special use of the book's inertia?

Explanation:

By pulling the thread slowly, we are not only putting a strain in the thread, but in the thread above the book, the book's weight adds to this pull. Thus compared to the strain below the book, this is much larger and the thread snaps wherever the strain is highest.

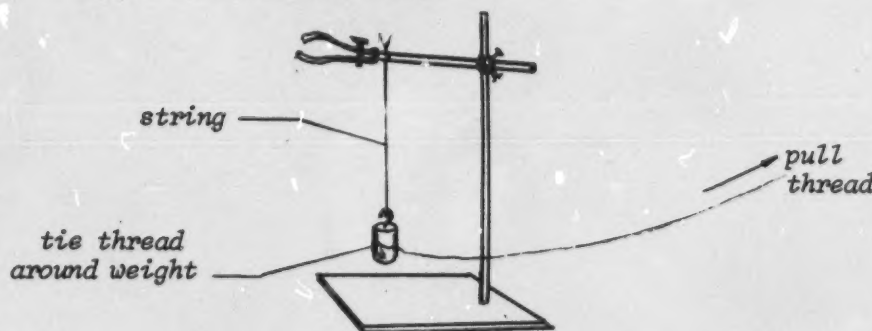
When a sharp jerk is exerted on the thread, the inertia of the book keeps the strain below the book. Although there is some strain in the thread above the book, compared to that below the book, the strain in the latter is still higher, and the thread snaps below the book.

SPACE SCIENCE

NEWTON'S FIRST LAW

14.6. WHAT BREAKS THE THREAD?

- Materials:**
1. A 1 kg mass or a stone of about 1 kg weight.
 2. A medium size string and sewing thread.
 3. A stand and clamp.

**Procedure:**

1. Hang the weight on a string tied to the clamp and stand.
2. Tie a length of sewing thread around the weight and pull slowly on the thread and show to students that it is possible to move the weight up high without breaking the thread.
3. Let the weight hang vertically and give the thread a sudden pull.
Ask: "What property of the weight made the thread break?"
4. Tie another thread to the weight, pull the weight and let it swing back and forth, but let your hand swing in phase with it (holding the thread), then suddenly stop the hand. Ask: "What property of the weight made the thread snap?"

Questions:

1. Which part of Newton's first law was the first break based on?
2. What events in daily life are based on this principle?
3. Which part of Newton's first law was the second break based on?
4. Can you mention any events in our daily life that are based on this second principle?

Explanation:

When the thread was broken the first time around, it was done by pulling the thread with a sharp jerk. The weight was at rest and it had the tendency to stay at rest. (First part of Newton's First Law). An application of this principle in daily life is pulling a table cloth out from under dishes, pushing a shovel under a heap of gravel, etc.

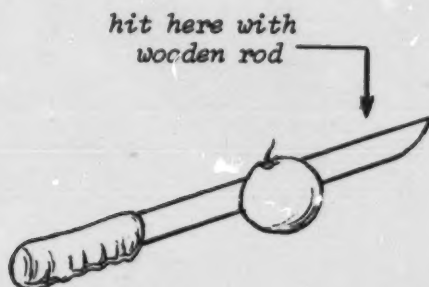
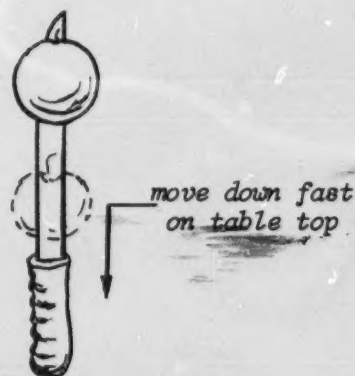
Breaking the thread the second time around was caused by a sudden stop of the moving hand, when the weight was still moving. The weight was in motion and it tended to stay in motion (second part of Newton's First Law). Events in daily life based on this principle are for example: the tightening of a loose axe on its handle, the sudden stop of a bus and the tendency of the passengers to keep moving forward, etc.

SPACE SCIENCE

NEWTON'S FIRST LAW

14.7. THE APPLE AND THE KNIFE

- Materials:**
1. Two fresh apples, a long kitchen knife.
 2. A wooden rod or stick (to hit the knife with).

Sketch ASketch BProcedure:

1. Press the kitchen knife about $\frac{1}{4}$ way through the first apple, hold the knife horizontally and hit the end of it with the wooden rod (see Sketch A). The apple will split in half illustrating the first part of Newton's First Law.
2. Now push the point of the kitchen knife all the way through the second apple. Ask the students: "How can I get the apple to slide closer to the handle?"
3. Hold the knife vertically above the table with the point upwards. Move the knife fast to the table top, hitting it hard with the knife handle. The apple will slide closer to the handle, illustrating the second part of Newton's First Law (see Sketch B).

Questions:

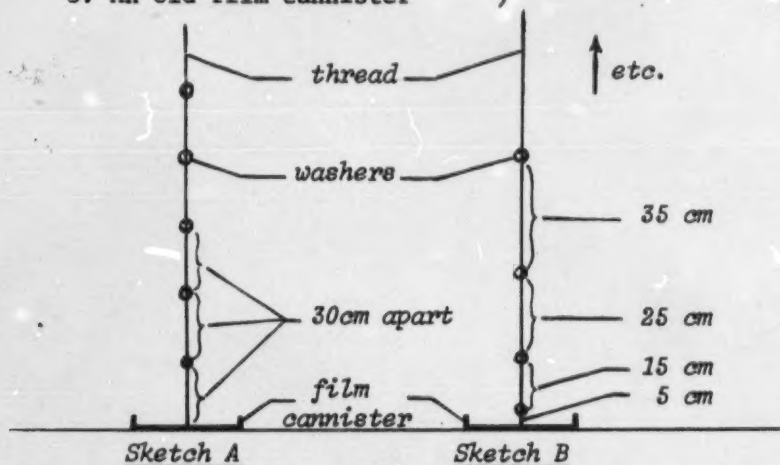
1. Why did the first apple split in two halves?
2. Was it the apple or the knife that followed Newton's Law?
3. In sliding the apple, which of the two (apple or knife) followed the second part of Newton's First Law?
4. What other daily examples can you name that are based on the first part and second part of Newton's First Law?

Explanation:

Newton's First Law states that: *an object at rest tends to stay at rest, and an object in motion tends to keep moving in a straight line.* The first apple split in two halves, because it tended to stay at rest when the knife was hit. The second apple slid closer to the knife handle because it tended to stay in motion when the knife was suddenly stopped by the table top.

14.8. THE FALLING WASHERS

- Materials:
- | | |
|---------------------------------|-------------------------|
| 1. Six or seven metal washers) | |
| 2. A strong thin thread) | for each demonstration. |
| 3. An old film cannister) | |

Procedure:

1. Tie the six or seven washers exactly 30 cm from each other on the thread and tape the end of the thread to the film cannister, such that the first (lowest) washer is 30 cm above it.
2. Stand on a chair and hold the thread tight above the cannister, while this latter is lying on the floor. Ask students: "What kind of tapping sound will the washers give us when I let them fall; even or faster and faster?" Now drop the washers (see Sketch A).
3. Tie seven washers to another thread the following distances from each other: cannister to first washer 5 cm, the next six washers: 15, 25, 35, 45, 55, and 65 cm from each other respectively.
4. Repeat point 2 (see Sketch B).

Questions:

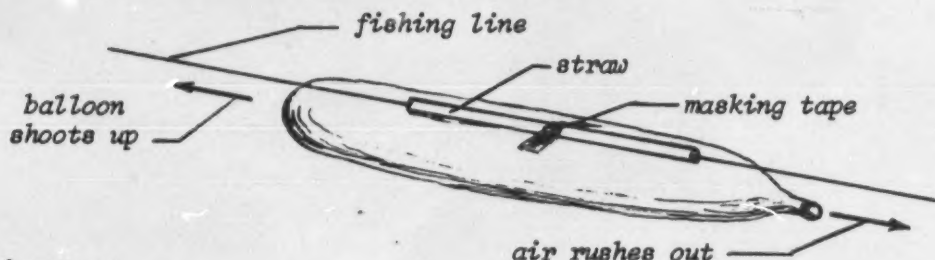
1. What kind of tapping sound did the washers give us in demonstration A, compared to that in demonstration B?
2. Which of the seven washers had the highest velocity when hitting the bottom?
3. What kind of motion is the free fall of the washers?
4. What gives a falling object its acceleration?

Explanation:

The falling washers are all subjected to gravity, which force imparts an accelerated motion to each of them. Newton's Second Law states that $F = MA$ (F =force, M =mass, and A =acceleration), and as the force and mass of the washers are equal, the acceleration of each of the washers is the same. The higher, the larger the velocity of the washer hitting the cannister. The distances between the washers in B were obtained from $S = \frac{1}{2}at^2$ (where S = distance, a = acceleration, and t = time).

14.9. THE BALLOON RACE

- Materials:**
1. Two long cylindrical balloons.
 2. A roll of fishing line (or smooth string).
 3. Two straws and masking tape.

**Procedure:**

1. Divide the class in two groups: there is going to be a race!
2. Have one student of each group tie one end of a 10 m length of fishing line to a pipe (or fire sprinkler) close to the ceiling at one end of the classroom (in the front).
3. Bring the other end of the fishing line to the rear of the classroom and have another student of each group push the fishing line through the straw, and hold the line tight.
4. Now have another student of each group blow up the balloon and hold the mouth closed (do not put a knot in it), and hold the balloon under the straw with its mouth facing the rear of the room.
5. Let another student tape the balloon to the straw (one strip of tape over the middle of the straw). You are now ready for the race.
6. Have the students release the balloon on the count of three.

Questions:

1. In which direction did the air of the balloon go?
2. What made the balloon shoot up?
3. Will a smaller or larger balloon shoot up faster?
4. If we want the balloon to shoot down, which way do we have to face the balloon's mouth?

Explanation:

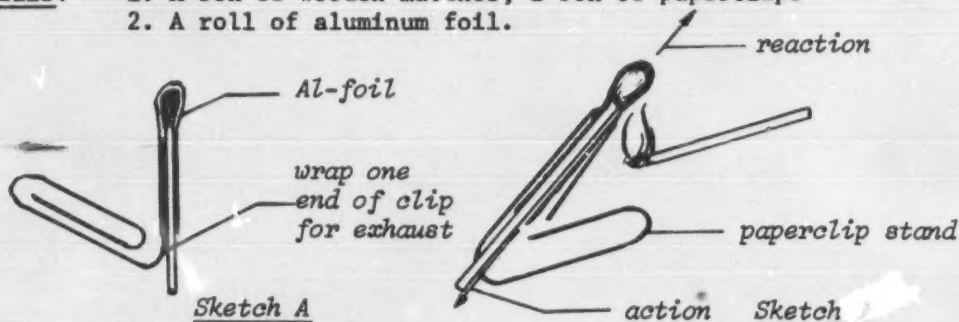
At the time that the balloon was held with its mouth closed at the rear of the room, all forces inside the balloon were balanced by an equal and opposite force. This will also be the case when we put a knot in the balloon's mouth or in the case of a closed pressured chamber in space (see Sketch 1 on the right).

When the balloon is released, the downward force is eliminated, and the resultant force is upwards. This is quite similar to the operation of a pressure chamber in a rocket or satellite. When a left turn has to be made, a valve on the right hand side of the vehicle is opened.

all forces
in balanceresultant
force: up

14.10. THE MATCH MISSILE

- Materials:
1. A box of wooden matches, a box of paperclips
 2. A roll of aluminum foil.

Procedure:

1. Distribute two matches and two paperclips and a strip of aluminum foil to each pair of students (let students work in pairs).
2. Demonstrate to students how to make the missile:
 - a. Wrap the match airtight with one end of the paperclip against the match stick (see Sketch A) and slide the clip out (this provides the exhaust pipe).
 - b. Bend out another clip to make a stand and lay the wrapped match against it (see Sketch B).
 - c. Heat the wrapped match head with another lit match.
3. Let students try to make the farthest reaching missile.

Questions:

1. What makes the "missile" shoot up?
2. What would happen if we heated the wrapped match without providing for an exhaust?
3. Does the angle of the bent up clip make any difference in the distance that the missile can reach?
4. What are other factors that influence the reach of the missile?

Explanation:

When wrapping the match (missile) with aluminum foil, we need to lay one leg of a paperclip (bent out) against the wooden stick, to provide an exhaust for the expanding gases when the match ignites. Sometimes when this exhaust is not working properly, a bursting of the aluminum foil near the match head will occur.

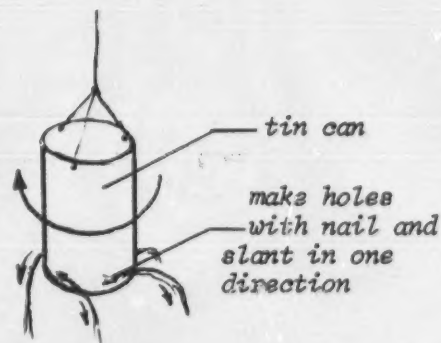
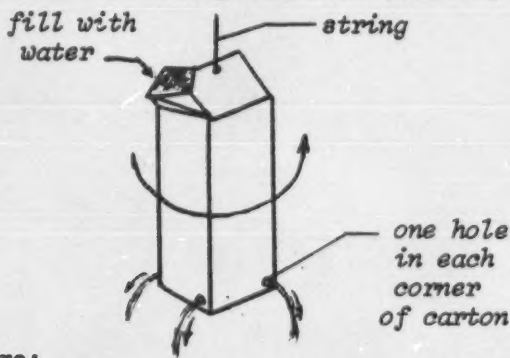
Factors that influence the reach of the missile would be:

- a. the weight of the missile--in our case the Al-foil, the less used, the lighter, but the less strong to keep the gases in.
- b. the match itself--some have larger heads, which would provide more power (try wrapping in an additional match head).
- c. the angle of blasting-- 45° angle is optimal; larger or smaller angles with the horizontal plane will give shorter distances.

This event is based on Newton's Third Law, which states that: For every action, there is an equal and opposite reaction.

14.11. THE MILK CARTON SPRINKLER

- Materials:**
1. An empty milk carton (2 l) or large tin can.
 2. A length of sturdy string.

Procedure:

1. Make four small holes, one in each right hand lower corner, in the sides of the milk carton.
2. Tie the string through a hole in the top of the carton, to hang it over the sink from a support (or from your hand).
3. Fill the carton full with water over a sink and let it hang from the string, and observe!

Questions:

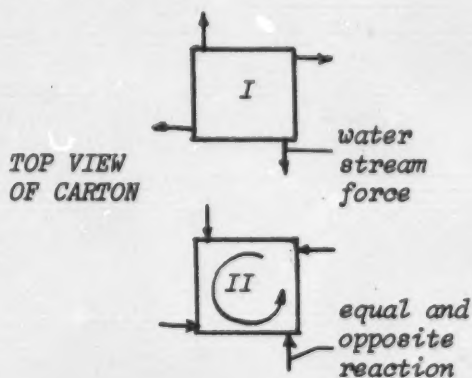
1. Looking from above, which way does the carton turn?
2. Is it possible to turn the carton in the opposite direction?
3. Where do the holes have to be placed in order for the carton to move in the opposite direction?
4. When would the carton stop turning?
5. What principle is this event based on?

Explanation:

This event is based on the Third Law of Newton: *action is reaction*. The action here is the water spouting out from each lower right hand corner of the side of the carton (see Sketch 1).

The reaction is an equal and opposite force on the carton (see Sketch 2), which makes the carton turn counter clockwise. In order to make the carton turn clockwise, the holes have to be placed in the left hand lower corner of each side.

A tin can could replace the carton by making nail holes near the bottom and slanting the nails in one direction.

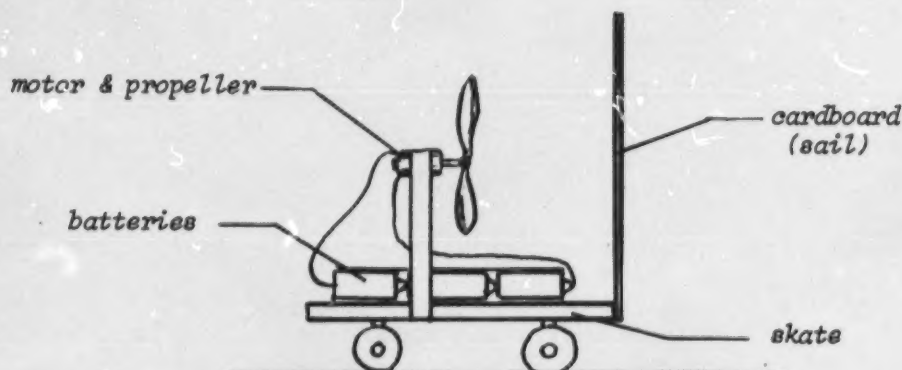


SPACE SCIENCE

NEWTON'S THIRD LAW

14.12. BLOW YOUR OWN SAIL?

- Materials:**
1. A roller skate, a small motor and propeller.
 2. Six 1.5V C-size batteries & 2 short lengths of bell wire.
 3. A piece of cardboard.

**Procedure:**

1. Mount the motor and propeller by means of wooden or metal strips on one end of the skate.
2. Tape the six batteries three by three in series together, and place them on the skate. Connect the wires from the batteries to the motor (leave the connection of one lead off for the moment).
3. Tape a piece of cardboard to the other end of the skate, such that the propeller blows air against the cardboard.
4. Ask the students: "What will the skate do when the fan is turned on?" Now complete the circuit and turn on the propeller.
5. Ask the students: "What will the skate do when the sail is taken off?" Take the cardboard away while the propeller is still turning.

Questions:

1. What forces are acting on the skate with fan on and sail on?
2. What forces are acting on the skate with fan on and sail off?
3. Why does blowing your own sail in a sailboat on a windless day not make you move forward?
4. What is the propeller blowing against when the sail is taken off?

Explanation:

With the propeller blowing against the cardboard, two forces of the same size but in opposite direction are working on the skate. When the cardboard or sail is taken away, that force is also eliminated, leaving one force in the opposite direction of the blowing as resultant force. For the same reason, blowing your own sail on a windless day will not work, as two equal and opposite forces are working on the boat. The same two equal and opposite forces are present when we push down on the table top. We feel the table pushing back against our hand.

SPACE SCIENCE

CONSERVATION OF MOMENTUM
NEWTON'S THIRD LAW14.13. THE RECOILING SKATE

- Materials:
1. A rollerskate and a stone.
 2. A heavy rubberband and a piece of string.

Procedure:

1. Cut the rubberband and attach the two ends to the front sides of the skate.
2. Tie a string to the center of the rubberband and pull it back like a catapult (see sketch) and attach the other end of the string to the back of the skate.
3. Place a medium size stone in front of the rubberband and cut the string with a pair of scissors (make sure that you do not touch the skate when cutting the string).

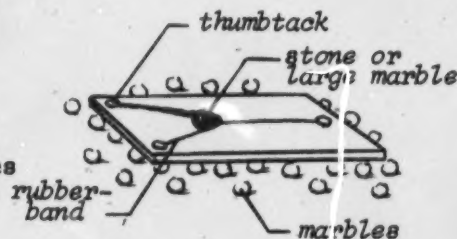
Questions:

1. What did the skate do when the stone was flung to the front?
2. How far did the skate recoil, and how far did the stone fly?
3. Would the skate recoil more or less with a larger stone?
4. What events in daily life would be similar to this one?
5. What other objects or set-ups could we use instead of the skate?

Explanation:

The action in this demonstration is the flinging of the stone by the rubberband to the front of the skate. The reaction is that the skate rolls backwards. The Third Law of Newton states that the force flinging the stone is equal to the force pushing the skate back. Because the masses of the two objects are not equal, the accelerations or velocities of the objects are also different. The momentum imparted on the stone is equal to the momentum of the skate: $M_1V_1 = M_2V_2$, where M_1 = mass of stone, V_1 = velocity of stone, M_2 = mass of skate, V_2 = velocity of skate. This conservation of momentum principle shows clearly in this event, where the stone has a much higher speed than the skate.

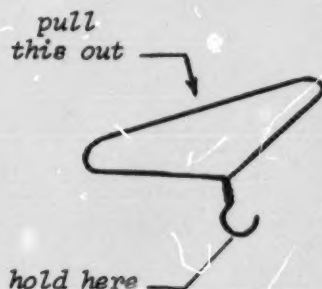
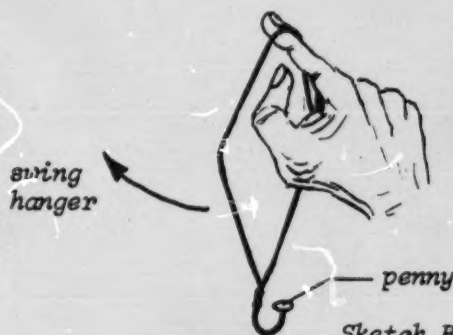
Other equipment that can replace the skate would be: a wooden board on marbles or straws. The rubberband and string could be attached to the board with thumbtacks (see sketch on right).



SPACE SCIENCE

CENTRIPETAL AND
CENTRIFUGAL FORCE14.14. THE STICKY PENNY

Materials: 1. A wire coat hanger, a penny (or any other coin).

Sketch ASketch BProcedure:

1. Pull the middle of the longest straight part of the hanger out (see Sketch A) and shape it into a long narrow shape (Sketch B).
2. Let the hanger hang on your right index finger (left, if you are left handed) and place a penny on the end of the wire (sometimes this end needs to be filed, especially if it is not flat).
3. Start to swing the hanger--first slowly back and forth, then do full loops (this needs a little practice, without dropping the penny).
4. Swing it slower (when ending the swing) and try to catch the penny.

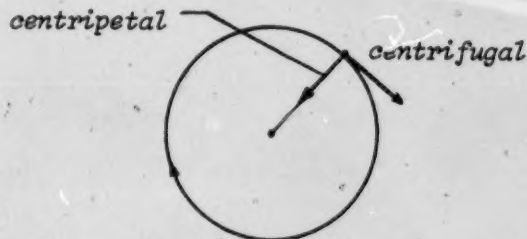
Questions:

1. How could the penny stay stuck against the end of the hanger?
2. What kept the penny against the coat hanger?
3. Would the coin still stick to the hanger if the swinging was done much slower?
4. What events in our daily life are similar to the moving penny?

Explanation:

The spinning of the penny gives it a centrifugal force holding the coin against the end of the hanger. The faster the spinning, the larger this centrifugal force; the slower the spinning, the smaller this force is, that keeps the coin up against the hanger. This is why the coin falls when the spinning is done too slow.

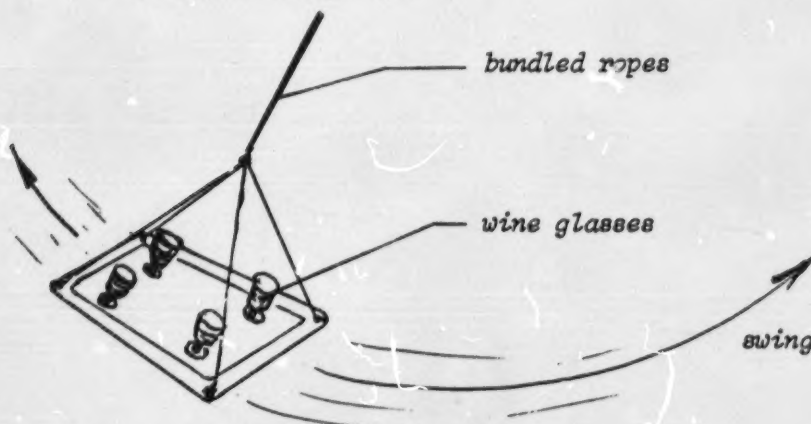
Centrifugal forces are applied in the automatic cloth washer, where the drum filled with clothes and water spins fast to separate the water from the clothes.



SPACE SCIENCE

CENTRIPETAL AND
CENTRIFUGAL FORCE14.15. THE FLYING WINE GLASSES

- Materials:**
1. Three or four plastic wine glasses.
 2. A sturdy plastic tray (or cardboard sheet).
 3. A strong flexible rope.

**Procedure:**

1. Drill four small holes in the four corners of the plastic tray.
2. Tie four pieces of rope to each corner of the tray (through the hole), bring them together to the center above the tray while it lies horizontally on the table, and tie a knot in all four strings together.
3. Tie another knot at the end (about 1 m away) of the bundled rope.
4. Place the four wine glasses on the tray and fill them $3/4$ full with red colored water (or real wine for that matter).
5. Start swinging the tray with the glasses and swing full loops, making sure that the tension in the rope is maintained.

Questions:

1. What made the wine stay in the glasses even when inverted?
2. What kept the glasses pressed against the tray?
3. What is the tension in the rope, while swinging, an indication of?
4. What would happen if we lost this tension in the rope, while the tray was in an upside down position?
5. How can we keep a rather even tension in the rope when swinging?

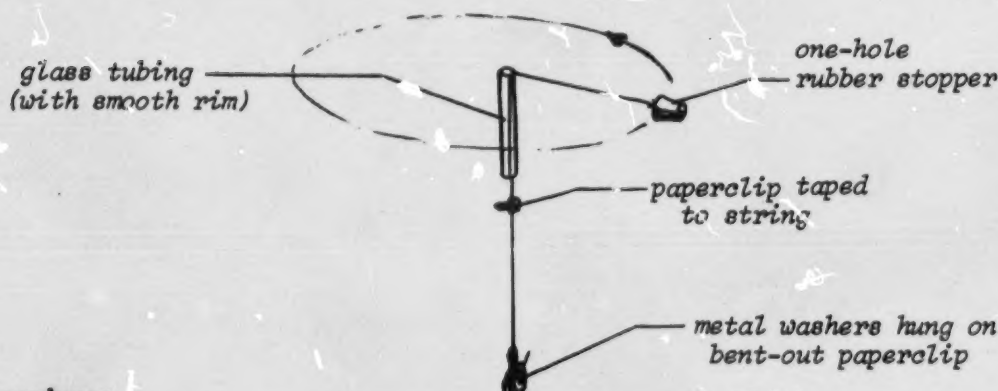
Explanation:

While in motion, the wine as well as the wine glasses tend to move in a straight line (second part of Newton's First Law). As they are kept in a circular motion, they are pressed against the tray (centrifugal force) and an equal center seeking force, *centripetal force*, is felt as a tension in the rope. The faster the swing, the stronger the tension in the rope. A rather even tension in this rope may be obtained by swinging the tray back and forth in the beginning and making the full loops when the swing almost reaches the horizontal position. (Practice by swinging a stone tied to a string).

SPACE SCIENCE

CENTRIPETAL AND
CENTRIFUGAL FORCE14.16. A MEASURE OF CENTRIPETAL FORCE

- Materials:**
1. A one-hole rubber stopper.
 2. A piece of glass tubing (about 15 cm long and nicely rounded off at the ends).
 3. Metal washers, a strong string, paperclips.

**Procedure:**

1. Thread the string through the glass tubing and let about 50 cm come out on each end of the tubing.
2. Tie the one-hole rubber stopper to one end and a paperclip to the other end of the string. Bend the paperclip leg somewhat out.
3. Hang a few washers on the bent-out paperclip and tape another paperclip about 30 cm from the paperclip end to the string (as an indicator to see whether the string is sliding up or down the tube).
4. Twirl the rubber stopper above your head by holding the glass tubing and swinging the stopper. Try to keep the paperclip indicator at the same height by adjusting the twirling speed.
5. Add more washers to the bottom paperclip: "What do you have to do with the twirling speed?"

Questions:

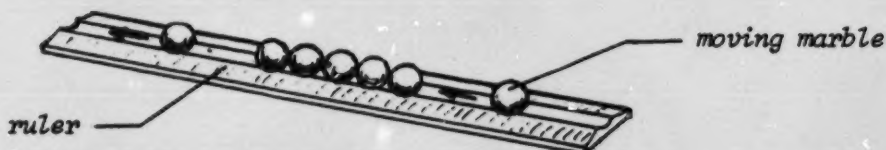
1. What is the relationship between rotational speed and no. of washers?
2. What relationship is there between speed of rotation and the diameter?
3. What relationship is there between diameter of swinging object and the number of washers?
4. How can we measure the centripetal force of the swinging stopper?

Explanation:

Holding the diameter of the swinging object (length of string above the tubing) constant, the faster the speed of rotation (number of revolutions per second), the more washers have to be hung on the bottom paperclip. The same goes for increasing the diameter when the speed is held constant. With the same number of washers, the smaller the diameter, the higher the speed of rotation, in order to keep the forces in balance. The centripetal force is the total weight of the washers hung on the paperclip.

14.17. THE FUNNY MARBLES

- Materials:
1. A plastic ruler (30 cm long, with center groove).
 2. Seven identical marbles.

Procedure:

1. Place the seven marbles in the groove of the ruler all next to and touching each other.
2. Now take one marble and let it roll from about 10 cm away, with some speed against the other six (only one will move away).
3. Place the marbles back on their original position and do the same with two marbles bumping against the remaining five.
4. Now separate four and before letting them roll against the remaining three, ask the students: "How many marbles will move away?"

Questions:

1. When one marble bumps against six, why does only one marble move away?
2. Are the other five marbles moving much after the collision?
3. How many would move away if five marbles were pushed against two?
4. Would a marble twice as heavy also move only one away?
5. Would the end marble move also faster when one is hitting the row with a faster speed?

Explanation:

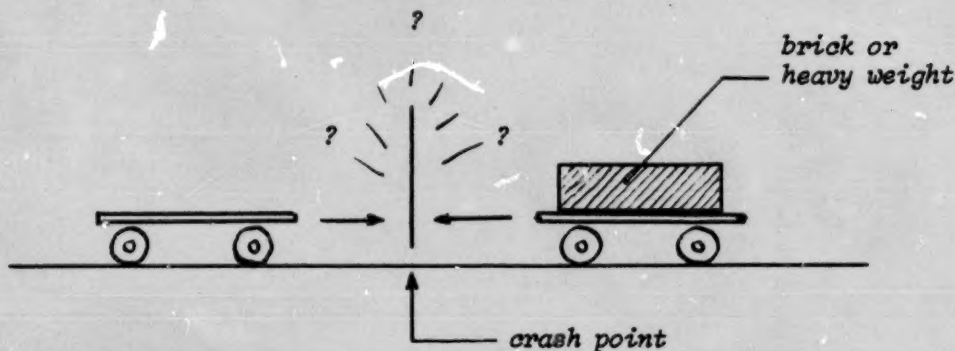
This event demonstrates the conservation of momentum. If all the marbles are identical in mass and size, whatever number rolls against a row of stationary ones, will move the same number away from the stationary row. These last moving marbles are just taking over the momentum that the first marbles were imparting to the row of stationary marbles. The momentum of a moving object is the product of its mass and its velocity (mv). When this is imparted to another stationary object, this second object will have the same initial momentum ($m_1v_1 = m_2v_2$). When both objects have the same mass, the velocity of the second object (v_2) will be the same as the first object's velocity (v_1). When the moving ball is twice as heavy ($m_1 = 2m_2$), then two balls with masses m_2 will move away. A faster moving marble will impart the same speed to a marble of the same mass. A marble with half the mass of a stationary one will only impart half the speed to the heavy marble.

Applications of this principle are encountered in head-on collisions of trucks and cars, where the truck driver almost always survives the accident but not the car passengers.

SPACE SCIENCE

CONSERVATION
OF MOMENTUM14.18. THE CRASHING SKATES

- Materials:**
1. A pair of skates (boards on marbles or straws will also do).
 2. A brick or other heavy weight.

**Procedure:**

1. Place a brick or other heavy weight on one of the skates.
2. Hold the two skates about a meter apart on a smooth surface (table or floor surface will do). Each skate can be held by one student).
3. Ask the students to push their skates toward each other with about the same speed on the count of three.

Questions:

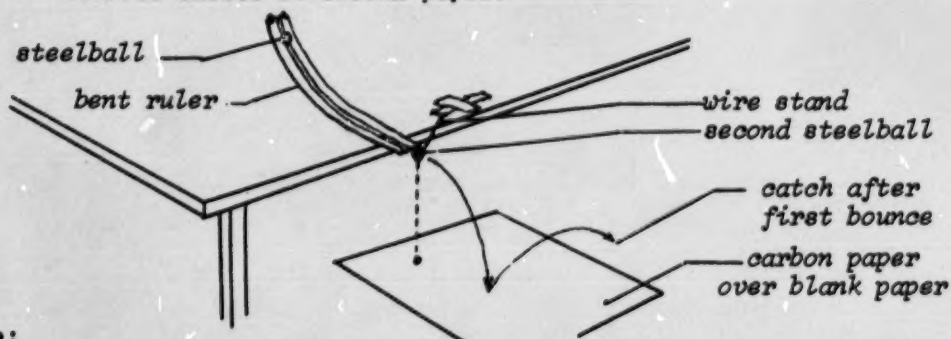
1. Which of the skates keeps moving in the same initial direction?
2. Which of the skates has a larger momentum?
3. If an egg were tied with a rubberband to each of the skates, which one do you think would most likely break?
4. What vehicles on the road can the skates be compared with?
5. In a head-on collision between a car and a truck, why does the truck driver usually survive the crash and not the car driver?

Explanation:

The skate with the brick on top has a much larger mass and thus a much larger momentum. At the point of impact, the object with the larger momentum will keep on moving in the same direction, whereas the one with the smaller momentum suddenly has to reverse its direction of movement. This is the main reason why in a head-on collision of a truck and a car, the truck driver usually survives the crash. At the point of impact, the truck with a much larger mass than the car, keeps on moving forward, although with a much slower speed. The car, however, is suddenly pushed in a reverse direction and the people in this car are flung forward. The velocity of the people upon impact is the sum of the speeds of both vehicles. If for example the truck was driving 100 km/h and the car 90 km/h, at the point of impact, the people in the car would have a speed of 90 plus a little less than 100—it is like having a speed of 190 km/h hitting a brick wall. Whereas the truck driver's speed would probably only be drastically reduced.

14.19. THE COLLIDING STEELBALLS

- Materials:**
1. Two medium size steelballs (about 1 cm diameter).
 2. A plastic ruler (30 cm long), metal washer.
 3. Rather stiff wire (coat hanger wire), masking tape.
 4. Four sheets of carbon paper.

**Procedure:**

1. Make two 90° hooks at both ends of the stiff wire, such that the length from hook to hook is exactly the length of the ruler.
2. Bend the plastic ruler and keep it bent by hooking the wire behind the ruler and bending the wire with it (keep the center groove free).
3. Tape the end of the ruler to the table edge (by taping only the back and sides of the ruler and keeping the center groove free).
4. Make a small steelball holder (stand) from a paperclip and tape this to the edge of the table, such that a steelball can sit just off center in front of the groove (see sketch).
5. Hang a metal washer from a string attached to the paperclip stand and find the point plumb under the point of impact.
6. Tape four carbon sheets on top of four white sheets to the floor, such that the rolling steelballs will hit the paper.
7. Let a ball roll off the ruler 4-5 times and make sure that you catch it after the first bounce. Place a second steelball on the stand in front of the groove and let the first ball collide into it, from the same height as when it was rolling by itself (catch both balls after their first bounce with the help of a student). Do this 4-5 times.
8. Take the sheets of carbon paper off and draw vectors from the point of impact (plumb under the end of the ruler) to where the single ball fell, and to where the two balls together bounced on the floor.

Questions:

1. What is the relationship between the vectors?
2. What do the vectors indicate about the force or momentum imparted from the first ball onto the second steelball?

Explanation:

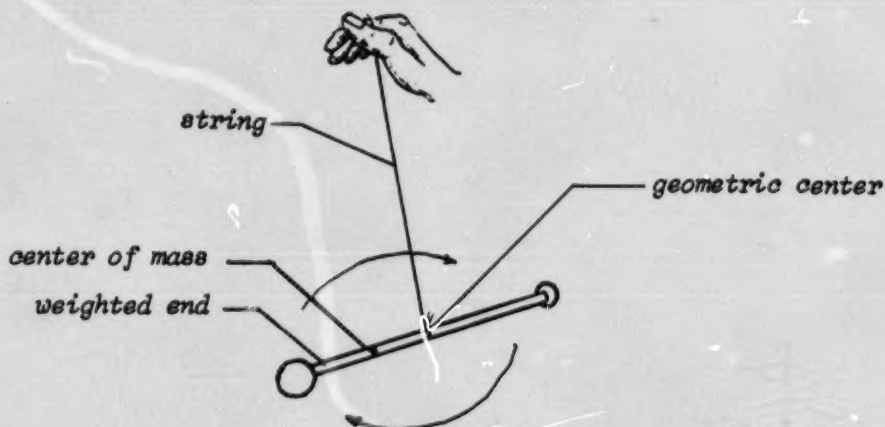
The vector of the ball rolling alone, is like the resultant of the two smaller vectors of the 2 balls falling together (see sketch).



SPACE SCIENCE

CENTER OF GRAVITY
ANGULAR MOMENTUM14.20. THE SPINNING PLANETS

- Materials:**
1. An aluminum or copper rod or tube (1 cm diameter, 50 cm long).
 2. A large and a small styrofoam ball, string.

**Procedure:**

1. Stuff one end of the tube with lead (solder wire would do fine) and attach the larger ball to the weighted end and the smaller one to the other end of the tube.
2. Find the balance point of the tube and mark the center of gravity by drawing a line around the tube with a marker.
3. Tie the string to the geometric center of the tube and show that the tube cannot balance horizontally at that point. Ask: "How can I balance the tube horizontally from the string?"
4. Now spin the tube while holding the string with the other hand, and keep spinning the tube around (the tube is now hanging horizontally from the string). Observe the marked center of mass/gravity!

Questions:

1. Did the geometric center stay in the middle of the rotating system?
2. Around what point did the system spin?
3. What kept the pipe hanging horizontally from the string?

Explanation:

All spinning objects spin around their center of mass, and this is why the marked spot stayed at the same place while the tube was spun. The geometric center, not being the center of mass, because the tube was weighted at one end, had to spin around the center of mass. This is the reason why we could keep the tube spinning. As the tube was spinning in a horizontal plane, it was actually kept horizontal and hanging horizontally from the string, even though it was not hanging from its center of balance (center of mass/gravity). The plane of rotation of the tube happened to be in a horizontal plane. If the tube could be spun at a higher speed, this plane of rotation could take up any position.

14.21. THE PAPERCARD BOOMERANG

Materials: 1. A stiff papercard (5x8" / 12x20 cm).
2. A pair of scissors.

Procedure:

1. Cut the papercard in the shape of a boomerang with a pair of scissors (see sketch).
2. Hold the paper boomerang with two fingertips at the bend, and slightly turn the legs upwards (by stroking them).
3. Hold the boomerang at an angle of 45° very lightly between index finger and thumb of your left hand, and flick it away with the middle finger of the right hand (see sketch).

Questions:

1. What made the boomerang return by itself?
2. What is most essential for a boomerang to be able to return?
3. If the paper boomerang were not spun, would it return?
4. Why does the boomerang have to be thrown slightly upwards?
5. Would other shapes work to make a boomerang?

Explanation:

When we flick the boomerang, a double movement is imparted to it: a spinning or fast rotation and a general upward motion. The spinning forces it to rise obliquely and *conserve its angular momentum in the plane of rotation* until the general upward momentum is exhausted. At this point it is still spinning, but instead of rising further, its weight causes it to descend. However, it does not drop straight down, but as it *tends to conserve its angular momentum* and also *its plane of rotation*, it slides back to the thrower in almost the same plane. The air resistance helps the boomerang to stay in its plane of rotation and it actually rides on the air, returning to the man who threw it in the first place.

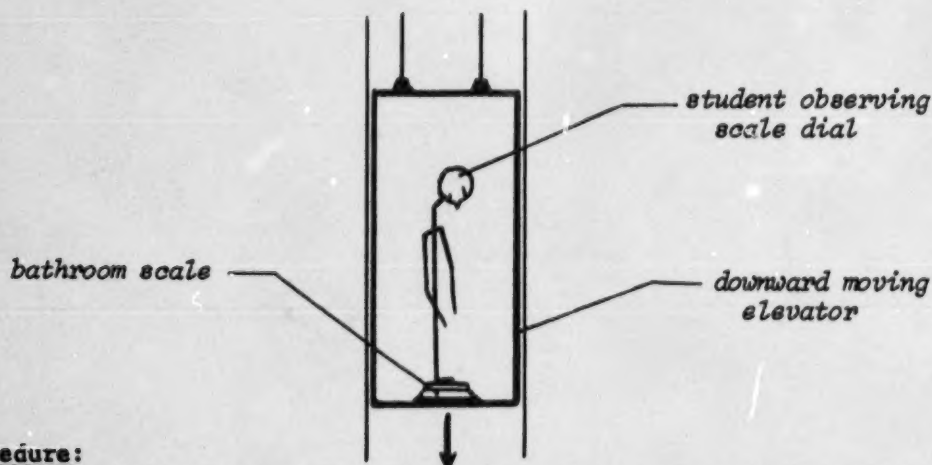
"Frisbees" may be thrown like a boomerang based on this same principle, when a partner for a catcher is not available.

SPACE SCIENCE

WEIGHTLESSNESS

14.22. THE FALLING ELEVATOR

- Materials:
1. A bathroom scale.
 2. A fast moving elevator.

Procedure:

1. Take the students in small groups into a fast moving elevator.
2. Let one student stand on the scale in the center of the elevator and have the other students observe the indicator of the scale.
3. Send the elevator up and down, and draw attention to the weight change at the start and end of the upward or downward motion.

Questions:

1. What did the scale indicate at the start of the upward motion?
2. What was your weight at the beginning of the downward motion?
3. How do you usually tell, without looking at the lights (indicators), which direction the elevator takes you?
4. What would happen to your weight if the elevator were to fall freely?
5. What is it that causes things to have weight?
6. Does weightlessness have any effect on the mass of objects?

Explanation:

It is the attraction of objects by the earth that gives them their weight. This weight is measured by the deflecting needle of a scale, usually based on the degree of stretch in a spring. In the motionless elevator, the weight of the student is the same as that on the solid floor. But, as soon as the elevator starts its upward motion, an added force upward is exerted on the scale, which increases the student's weight. This force, however, is only exerted during the accelerated part of the upward motion.

When the elevator moves down, a downward force is exerted, resulting in a smaller upward force on the scale, and thus showing a lower weight. If the elevator were to fall freely, a *constant acceleration* and thus a force downward is exerted on the scale, eliminating the upward reactive force of the student's weight, resulting in weightlessness of the person.

CHAPTER 15

WHAT ARE SOME PHENOMENA ABOUT EARTH AND THE MOON ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

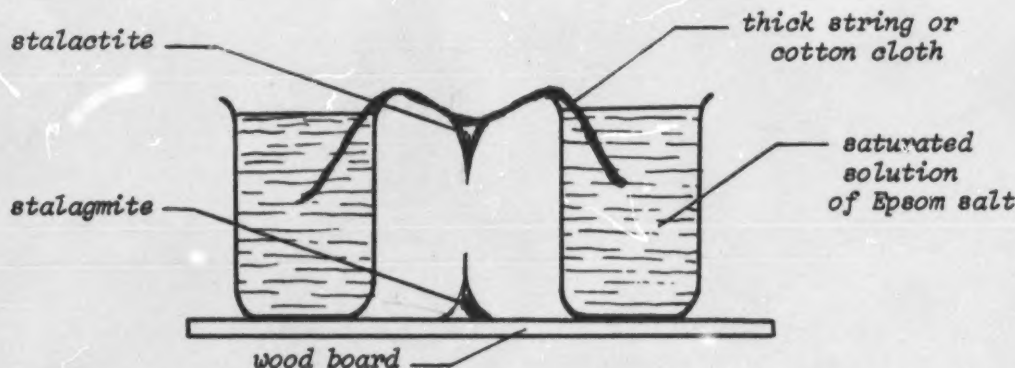
- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

- Dissolved salts in ground water are deposited when the water evaporates, as in stalactite and stalagmite formation.
- Some rocks are softer and more soluble in dilute acids than others.
- Erosion and weathering may occur by plant growth or the freezing of water.
- Continents and ocean floors stay at the same level in spite of erosion and deposits of material, because of the liquid mass in the inner core of the earth (isostatics).
- Volcanic and geyser eruptions are caused by pressures in deeper lying layers of the earth.
- The phases of the moon are caused by the different positions of the moon in relation to the earth and to the sun.
- A solar eclipse is caused by the moon's shadow on the earth.

15.1. MAKE STALACTITES & STALAGMITES

- Materials:**
1. Magnesium sulfate (Epsom salt)
 2. A large beaker and stirrer.
 3. Two small beakers, a thick water-absorbent string or cloth.

**Procedure:**

1. Make a saturated solution of magnesium sulfate in water in the large beaker, by dissolving as much of the powder as you can in about 200 ml of water (until some solid stays undissolved).
2. Fill the two small beakers with the saturated solution and place a thick water-absorbent string or cloth between the two beakers, such that the center part hangs somewhat lower than the beaker's rim (see sketch above).
3. Let stand for a few days and observe.

Questions:

1. Which cone is called stalactite and which stalagmite?
2. How were the cones formed?
3. What material are the stalactite and stalagmite made up of?
4. What other materials can we use instead of the string or cloth?
5. Where in nature are stalagmites and stalagmites formed?

Explanation:

Stalactites and stalagmites in nature may be found in *underground caves*. Groundwater which contains dissolved salts and minerals, drips from the ceiling of the cave. While the drop hangs down, the water evaporates and leaves some of the salts deposited on the ceiling, forming the stalactites. Similarly, the stalagmites are formed on the bottom of the cave. The water drops containing the dissolved salts evaporate and keep depositing the salts on the same spot, leaving a cone of salts that were dissolved in the water.

This demonstration is a simulation of the stalactite and stalagmite formation in caves, which may have taken centuries to build up. Water-absorbent paper towel, blotting paper, etc. may be used instead of the string or cloth.

EARTH SCIENCE

EROSION &
WEATHERING15.2. CAN STONES DISSOLVE?

- Materials:
1. Pieces of limestone, marble, granite.
 2. Vinegar or dilute hydrochloric acid.

Procedure:

1. Observe the pieces of limestone, marble, and granite. Ask: "How do they differ? How do we know which is which?"
2. Place a few drops of vinegar or dilute HCl on a flat surface of each of the rocks and observe for chemical reaction.
3. Let stand for a few minutes, then place again a few drops of acid on each of the rocks. Ask: "Which one reacted most?"
4. Scratch the surface of each of the stones with the fingernail or a pen knife. Ask: "Which one is the softest? Which the hardest?"

Questions:

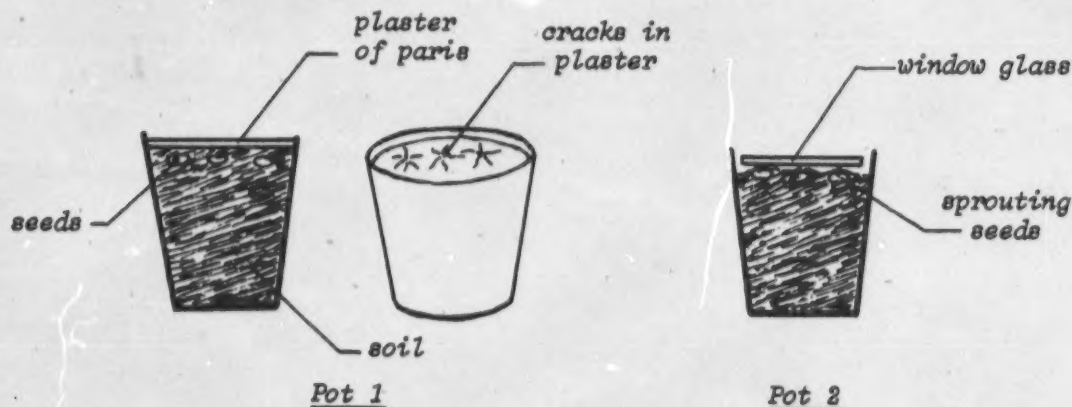
1. How can we distinguish which stone is which?
2. What are the characteristics of each of the stones?
3. Which of the stones would be eroded most when subjected to the same erosive forces in nature?
4. How would you tell the difference between common salt and marble?
5. What other methods are geologists using to identify minerals?

Explanation:

The limestone is the softest of the three and granite the hardest. Limestone can most likely be scratched by the human fingernail (number 4 in the hardness scale), whereas the other two cannot. Limestone reacts most with the vinegar or dilute hydrochloric acid. Marble does react with the acid, but not as readily, because of its more compact structure. Chemically they are the same (calcium carbonate). Other methods that geologists use to identify minerals are: breaking the rock and observing the crystal structure with magnifying glasses or microscopes.

15.3. CAN PLANTS BREAK ROCKS?

- Materials:**
1. Dried lima beans, red beans, or corn seeds.
 2. Two small flowerpots & soil.
 3. Plaster of paris (or 'Polyfilla').
 4. A piece of window glass (the size of the pot).

**Procedure:**

1. Soak six to ten beans or seeds in water and let stand overnight.
2. Plant the seeds just under the soil surface in the pot, and water.
3. Cover the soil with 1 cm thick layer of plaster of paris (or Polyfilla); cover the other pot (with planted seeds) with window glass.
4. Observe and examine the two pots daily (in pot 1, cracks will appear in the plaster; in pot 2, the glass will be lifted).

Questions:

1. Why did the seeds have to be soaked before planting?
2. What happened to the plaster of paris after a few days?
3. What did you observe the window glass was doing after a few days?
4. Can we find places where plants have broken through asphalt, brick or cement?
5. If sprouting seeds have such strength, can you imagine how strong the roots of tall trees are?

Explanation:

This demonstration may be used as an activity for students to discover the strength of sprouting seeds, and how they can cause rocks to move out of their path of growth or break them up into smaller pieces.

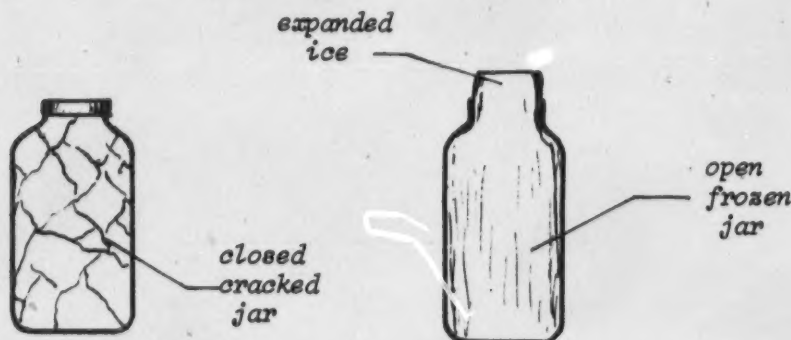
Take the students out on the school yard to find plants that have grown through cracks in the sidewalk, lower edges of the wall, or other such places.

Roots of tall trees can easily break foundations of concrete when the trees are planted too close to the buildings. Large rocks can similarly be broken up by the growth of roots, causing pulverization or erosion of the rocks.

EARTH SCIENCE

EROSION &
WEATHERING15.4. HOW CAN WATER BREAK ROCKS?

- Materials:
1. Two empty jars (one with a screw lid).
 2. A piece of sandstone, limestone, and pumice.
 3. Four small polyethylene bags.

Procedure:

1. Fill the two jars brimfull with water.
2. Close one off with the screw lid, leave the other open, and place both jars in the freezer, after wrapping them in a plastic bag.
3. Observe what happened to the jars after three or four hours, or at the end of the day.
4. Soak the pieces of rock in water and place them in the freezer, after each one is wrapped in a plastic bag.
5. Observe what happened to the rocks at the end of the day.

Questions:

1. What happened to the two jars with water after the water froze?
2. Would the closed jar also break if it was not completely filled?
3. How much air space do we need above the water in order for the jar not to break in the freezer?
4. How similar is this breaking of the filled and closed jar in the freezer to the breaking up of rocks in nature?
5. In what regions of the world does this process of erosion occur?

Explanation:

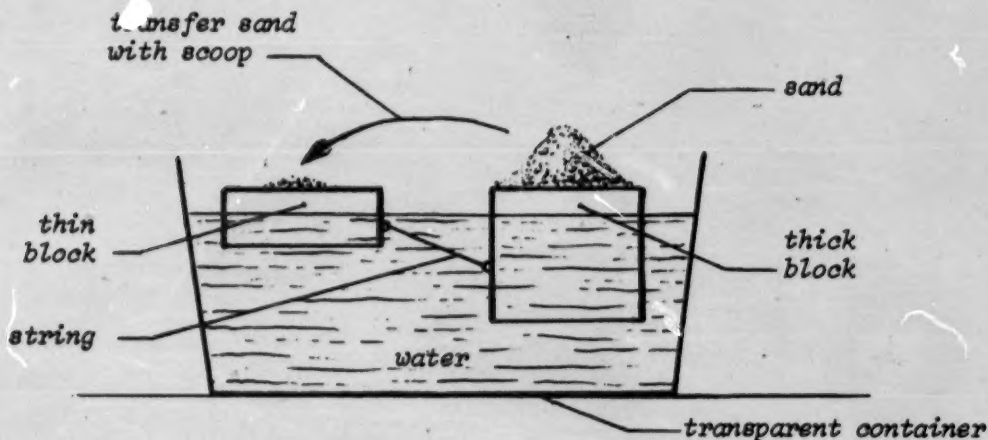
The jar that was closed off broke into pieces after the water froze. This happens because water expands when it changes into ice. This freezing action is so strong, that it can break basement walls when the drainage outside the basement is not adequate.

Similarly, when water seeps into cracks or pores of rock, especially of pumice, and the temperature drops below freezing, the water freezes, expands and breaks up the rock. This type of erosion only occurs in regions of the world where temperatures drop below 0° C in winter.

EARTH SCIENCE

ISOSTATICS
EROSION15.5. WHY DO ERODED MOUNTAINS KEEP RISING?

- Materials:**
1. A thin and a thick block of wood.
 2. Sand and a scoop, a short piece of string.
 3. A transparent plastic container (or aquarium).

**Procedure:**

1. Tie two short pieces of string to the wooden blocks in such a way that about 10 cm is separating the pieces of wood.
2. Fill the large container with water and let the two wooden blocks float on the water surface.
3. Place a heap of sand on the thick block, such that it just floats above the surface of the water.
4. Transfer the sand little by little to the thin block with the scoop. Observe the rising and sinking of each block.

Questions:

1. What do the two blocks represent?
2. How was the erosion of the mountain simulated?
3. How was the total height of the mountain affected by the transfer of the sand?
4. Why does the ocean floor stay relatively stable in depth?

Explanation:

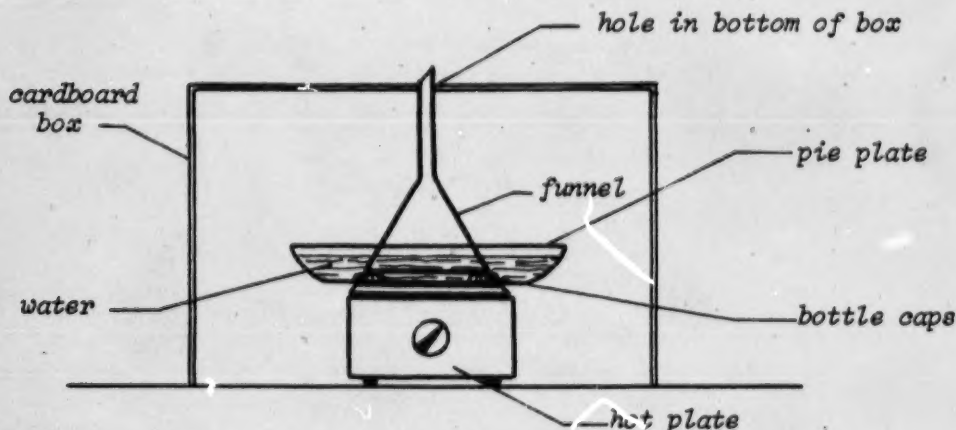
The thick block of wood and the sand on top of it represent land with a mountain on it. The rain water and the weathering erodes the mountain and transports the eroded material to the ocean floor: represented by the thin block of wood. The erosion process is simulated by the moving of the sand with the scoop. The total height of the mountain above the water surface stays about the same, even after taking some sand off, because the block gets lighter and floats higher above the water surface.

Similarly, the ocean floor (thin block) does not get much higher relative to the water surface, as it becomes heavier and thus floats lower.

EARTH SCIENCE

GEYSER ACTION &
VOLCANIC ACTION15.6. HOW DOES A GEYSER WORK?

- Materials:**
1. A pyrex or aluminum pie plate.
 2. A medium size Pyrex funnel, three bottle caps.
 3. A hot plate or burner & stand, cardboard box.

**Procedure:**

1. Fill the pie plate half full with water and place the funnel on it, resting on the three bottle caps.
2. Place the pieplate on the hot plate or over the burner (see sketch).
3. Heat the water in the pie plate until boiling. Make a hole in the bottom of the box, cover the whole set-up with it and let the funnel stem protrude through the hole. Observe geyser action!

Questions:

1. What did the water do when it was heated?
2. What made the water spurt out of the funnel?
3. What can we compare the cardboard surface to?
4. Why does the hot water inside the earth escape to the surface?
5. What will happen when the heat is turned off?
6. How can we let the geyser erupt again?
7. How similar is volcanic action compared to geyser action?

Explanation:

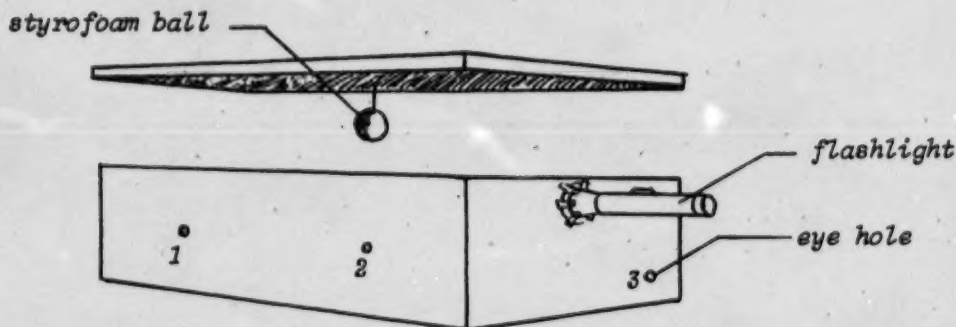
By heating the water, it expands. At the moment that it boils, water vapor is formed, pressure is built up under the funnel and this force pushes the water out of the funnel. When the heat is taken away, the water cools down and the eruptions stop. In order to start the geyser to erupt again, the water needs to be heated to boiling.

This demonstration illustrates clearly the similar working of the hot water under the earth's surface, the build-up of pressure, and the release of the water through small cracks in the earth's surface: called the *Geyser*. Volcanic action is quite similar except that instead of water, we have molten lava, which comes out of the mouths of volcanoes.

To make it inquiry oriented, conceal the set-up and let students find out the reason why the water spurts out.

15.7. WHAT CAUSES THE PHASES OF THE MOON?

- Materials:**
1. A large shoebox, carbon paper or other black paper.
 2. A styrofoam ball (about 5 cm in diameter).
 3. A small strong flashlight, masking tape, black thread.

**Procedure:**

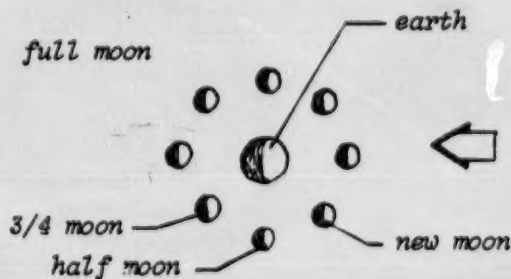
1. Cover the inside of the shoebox with black paper by gluing or placing small rolls of masking tape between the paper and the box.
2. Suspend the styrofoam ball from a black thread of about 2 cm long, and tape the thread against the center of the lid (see sketch).
3. Cut a hole the size of the flashlight at the end of the box and seal any space around it with masking tape.
4. Make five eye holes in the sides of the box: two on each long side and one at the end of the box obliquely under the flashlight.
5. Put the lid with the suspended ball on the box and seal the edges around it with masking tape.
6. Look through the eye holes and observe the ball (with the flashlight on) in the order numbered in the sketch.

Questions:

1. What do you see when you look through the eye holes?
2. Turn the flashlight off; what do you see through the eye holes?
3. Looking through which of the holes gives you a similar picture as looking at the *new moon*?
4. What is it that causes the phases of the moon?

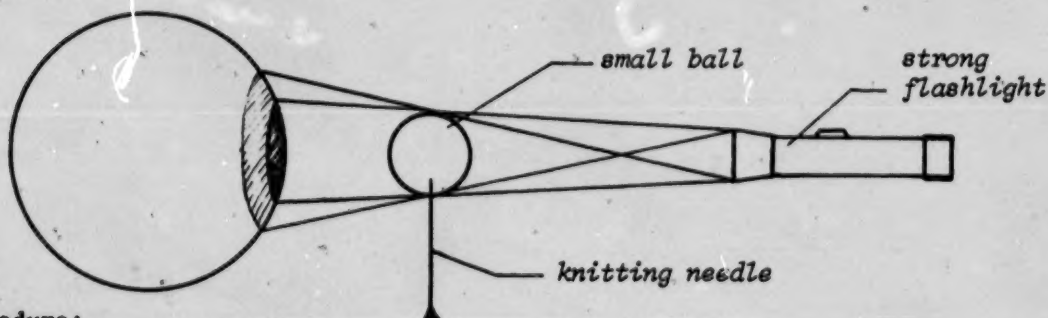
Explanation:

Perhaps the best way to explain seeing the eight different phases of the moon is the illustration on the right. A quarter *new moon* would correspond with looking through hole 1, *half moon* and three quarter moon with looking through hole 2, *full moon* with looking through hole 3, etc.



15.8. WHAT CAUSES AN ECLIPSE?

- Materials:**
1. A strong flashlight, slide projector, or other light source.
 2. A large (20 cm diameter) solid color sphere.
 3. A small (5 cm diameter) rubber or styrofoam ball.
 4. A knitting needle.

**Procedure:**

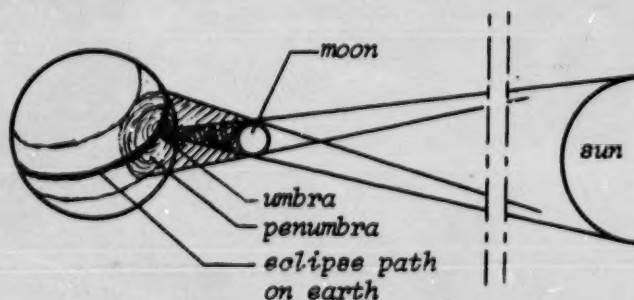
1. Stick the knitting needle into the small ball, so that you can hold it between the light source and the large ball without casting a shadow of your hand.
2. Hold the smaller ball between the light source and the large sphere and adjust the distance from the sphere, such that the small ball casts a dark shadow in the center and a greyish shadow on the edges.

Questions:

1. What does it mean if something is eclipsed?
2. For a solar eclipse to occur, how must the earth, sun, and moon be positioned in relation to each other?
3. Would all people on earth be able to see a solar eclipse when it occurs?
4. At what time (day or night) can a solar eclipse be observed?
5. How must the earth, sun, and moon be positioned in relation to each other, in order for a lunar eclipse to occur?
6. What are safe ways to observe a solar eclipse?

Explanation:

The light source represents the sun, the large sphere the earth, and the small ball the moon. In order for a solar eclipse to occur, the moon must be positioned between the earth and the sun. For a lunar eclipse to occur, the earth must be between the sun and the moon. Only those people living in the eclipse path can see either a partial (those in penumbra) or a total eclipse (those living in the umbra).



SECTION IV

LIVING THINGS

This section consists of two chapters, one dealing with plants and the different variables that are influencing their growth, and the last chapter contains demonstrations and activities about human biology.

Chapter 16 deals with the variables affecting the growth of a plant, like: light, gravity, the amount of water. Osmosis and capillary action, respiration and photosynthesis are also dealt with.

Chapter 17 contains demonstrations and activities to start off lessons about the senses, the nervous system, the circulatory, the respiratory, and digestive system in the human body.

CHAPTER 16

WHAT VARIABLES ARE AFFECTING THE GROWTH OF PLANTS ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

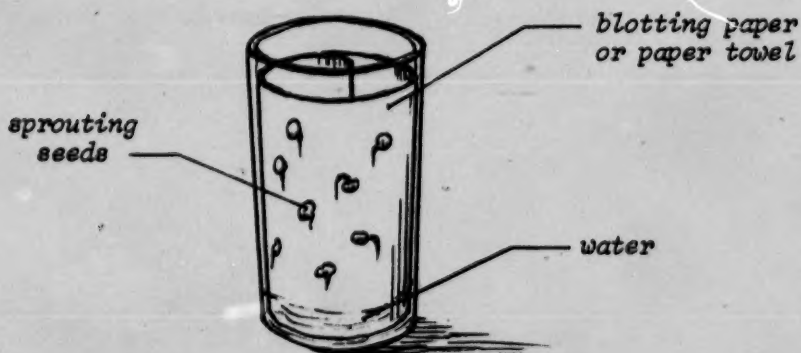
- Conditions for germination of seeds are: moisture, warm temperatures, and air supply.
- Plants grow in the direction of the light source.
- Plant roots grow down towards the center of the earth.
- The parts of a plant that are above the ground grow vertically up.
- Water moves into the plant roots by osmosis.
- Water moves into higher parts of the plant by capillary action.
- Leaves give off water vapor.
- Green leaves exhale oxygen in sun light and carbon dioxide in the dark.
- Photosynthesis is the production of sugar from water and carbon dioxide in chlorophyll of the plant leaf.
- Chlorophyll production needs sun light.

PLANTS

GERMINATION

16.1. HOW DO SEEDS GERMINATE?

- Materials:**
1. Small seeds (mustard, radish, green beans, etc.).
 2. Blotting paper or several layers of paper towel.
 3. A drinking glass or beaker.

**Procedure:**

1. Cut a rectangular piece of blotting paper as wide as the glass is tall (if paper towel is used, triple or quadruple the layers).
2. Moisten the paper and place the seeds on it.
3. With the seeds sticking to the moist paper, roll the paper in a cylinder slightly smaller in diameter than the glass and insert the roll into the glass.
4. Let the paper stand against the glass wall and pour some water into the glass to keep the paper moist.
5. Put the glass in a warm place and cover loosely (make sure that some water stays in the glass at all times).

Questions:

1. Which seeds sprouted first? Which last?
2. In which direction did the rootlets grow?
3. How could the paper stay moist at all times?
4. Why did the glass have to be loosely covered?
5. What are the conditions for germination of seeds?

Explanation:

In three to six days, depending on what seeds, the seeds will sprout and send their rootlets in a downward direction: this is in the direction of the water. The blotting paper stayed moist, because the water worked itself up through *capillary action* in the paper fibres.

The glass has to be covered in order to prevent fast evaporation of the water, but it has to be done loosely so that the seeds are not cut off from the atmospheric air.

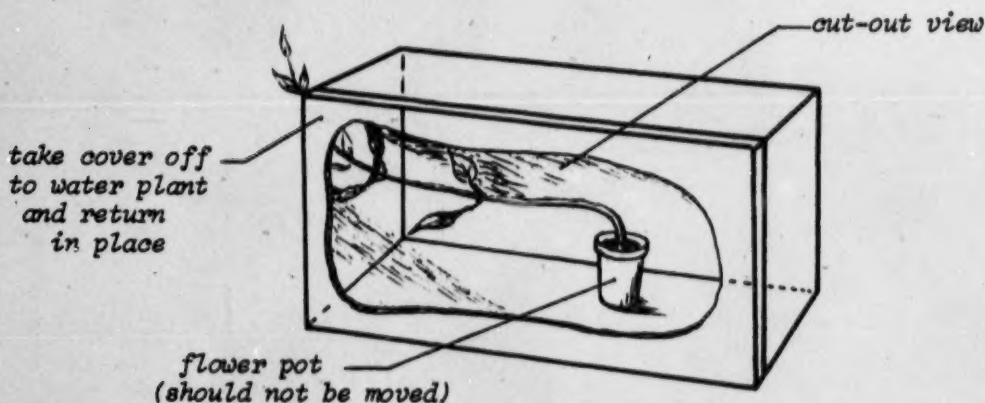
The ideal conditions for germination of seeds are: presence of moisture, warm temperatures, and supply of air.

PLANTS

GROWTH

16.2. THE BENDING PLANT

- Materials:**
1. Bean or radish seeds.
 2. A small flower pot and soil.
 3. A cardboard box.

**Procedure:**

1. Plant one seed in one small flower pot and water daily.
2. After the seed has started to sprout, let it grow until it is about 5 cm high.
3. Now place the pot in the cardboard box in which a hole has been cut out in its end side (see sketch).
4. Keep the box close to a window to let light in through the hole.
5. Keep the pot in the same position, water daily for the next few days (replace cover after watering), and observe plant growth!

Questions:

1. How did the plant grow? In which direction?
2. How would the plant grow, if the pot were turned around every day?
3. How would the plant grow, if the box were turned around every day?
4. How would the plant grow, if the box cover were left open?
5. What do plants need in order to grow?

Explanation:

Plants grow in the direction from where the light comes, in this case towards the hole in the box, and even through the hole when left for a longer time. This shows that the plant needs light in order for it to grow. By turning toward the light (hole in the box) its leaves will catch more light and thus grow better.

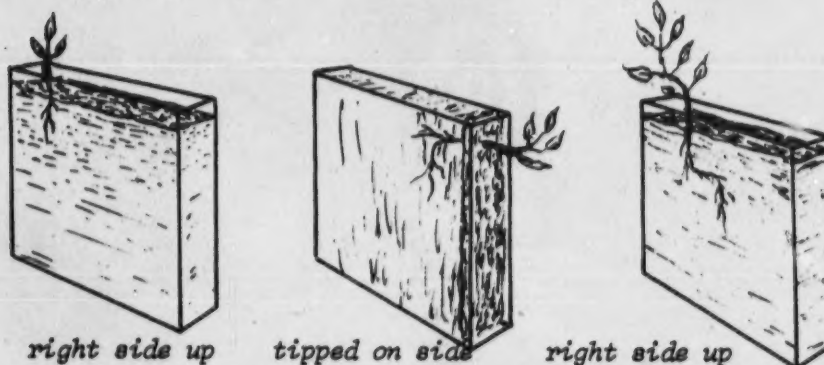
If the plant were turned half way around every day, it would grow straight up, or keep bending back and forth. If the box were turned, the plant would still bend towards the hole. Without the box cover, the plant would just grow straight up (and slightly bend toward the window).

PLANTS

GROWTH

16.3. THE CROOKED ROOT

- Materials:
1. A small young plant and potting soil.
 2. A flat, square, transparent container or two 10 x 10 cm pieces of window glass & three 1 x 1 x 10 cm wooden blocks.
 3. Cardboard or black paper.

Procedure:

1. If a transparent thin square container (chemical cell) is not available, construct one by taping two pieces of window glass against each other with the three wooden blocks in between them.
2. Fill the container with potting soil and place the plant on one side in the soil of the container.
3. Cover the sides of the container with cardboard or black paper and let the plant grow for 3-4 days.
4. Tip the container on its side (cover the open top with cardboard if the soil tends to fall out), and let the plant further grow.
5. After another 3-4 days, turn the container right side up again.
6. Point 4 and 5 can be repeated once more, then remove the covering cardboard or black paper and observe the roots.

Questions:

1. How did the roots of the plant grow?
2. In what direction do roots grow?
3. Why did the sides of the container have to be covered?
4. On the day just before turning the container right side up, in which direction did the plant grow?

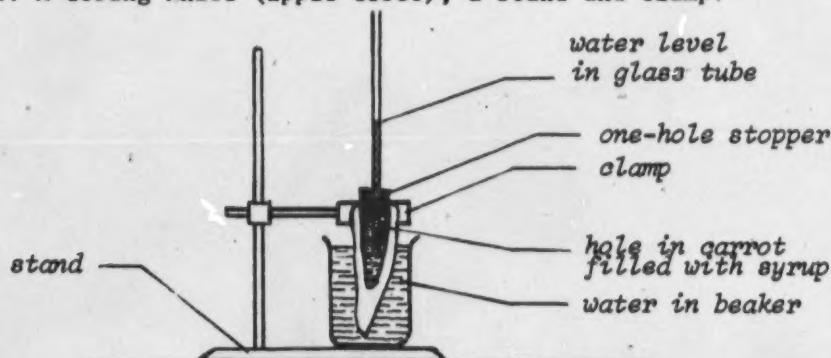
Explanation:

Plant roots grow downwards in a vertical direction. They grow towards the center of the earth, opposite to the direction of the plant parts that are above the ground, which grow vertically upwards. Regardless of the position of the container, the roots will grow downwards, this is why turning the container on its side makes the roots turn in their direction of growth. The covering of the sides of the container keeps the roots in the dark, simulating the earth or an opaque pot of soil.

PLANTS

GROWTH
OSMOSIS16.4. THE WATER-SUCKING ROOTS

- Materials:**
1. A beaker (250 ml), a one-hole stopper, a glass tube.
 2. A carrot or a cylinder shaped potato, syrup (sugar), candle wax.
 3. A coring knife (apple corer), a stand and clamp.

**Procedure:**

1. With the coring knife, cut a hole in the carrot or potato about three-quarters down its length, such that the one-hole stopper will fit in it and close it tightly (see sketch).
2. Insert a 20 cm long glass tube in the one-hole stopper.
3. Fill the hole in the carrot or potato with syrup or a concentrated solution of sugar in water brim full.
4. Push the stopper with the glass tube in the hole (liquid level should rise in the tube) and seal any openings between the stopper and the carrot or potato with candle wax (light a candle and let the melted wax drop on the places that you want sealed).
5. Mark the liquid level in the glass tube with a piece of masking tape, a grease pencil, or a rubberband.
6. Clamp the carrot or potato and immerse it in water. Observe the water level in the glass tube at the end of the period.

Questions:

1. What made the water level in the glass tube rise?
2. Would this water level also rise if the tube were filled with plain water? With salt water?
3. Why did the stopper have to be sealed with wax?
4. What would happen if the carrot and tube were filled with plain water and the beaker with the sugar solution?

Explanation:

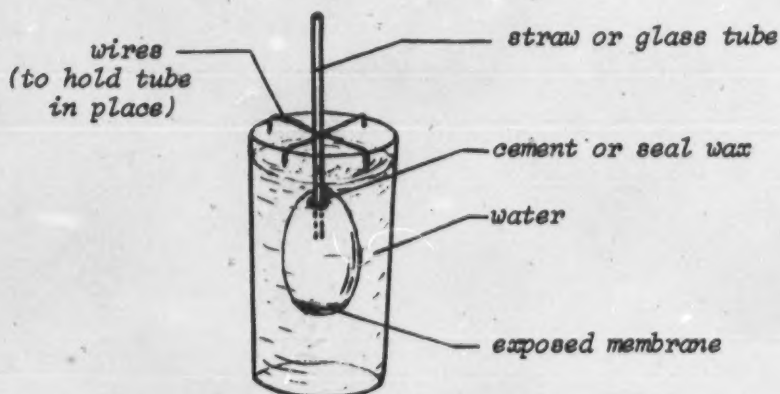
The skin, tissue, and fibres of the carrot or potato act like a *semi-permeable membrane*, letting only the small water molecules through, but not the large sugar molecules. This makes the water move from the beaker into the carrot and up the tube. If the concentration of sugar is higher in the beaker compared to that inside the carrot, the water will move out of the carrot and thus the water level in the tube will go down.

This action and migration of water molecules through a semi-permeable membrane is called: *osmosis*.

PLANTS

GROWTH
OSMOSIS16.5. MAKE AN EGG OSMOMETER

- Materials:
1. A fresh chicken egg, soda straw (transparent) glass tubing.
 2. Dilute HCl or strong vinegar, household cement or sealing wax.
 3. A saucer, a drinking glass, a thin wire.

Procedure:

1. Put some dilute hydrochloric acid or strong vinegar on the saucer and hold the large end of the egg in the liquid until the shell has been eaten away, leaving the thin membrane exposed.
2. After an area of about 4 cm^2 of the thin membrane has been exposed, rinse the acid off with fresh water.
3. At the other end of the egg, make a hole the size of the straw or glass tube (take care that the egg does not crack).
4. Insert the straw or glass tube through the hole into the interior of the egg and seal any excess opening between the egg and the tube off with cement or wax (candle wax will do).
5. Place the osmometer in a glass of water and hold the tube in place (vertically up) by wrapping the thin wire around it and bending the wire over the rim of the glass (see sketch).
6. Let stand for a few hours and observe liquid level in the tube.

Questions:

1. What do you think the egg shell consists of?
2. Why does the seal between the egg and the tube have to be absolutely tight? What would happen if it were not?
3. Why did the liquid level in the tube rise?

Explanation:

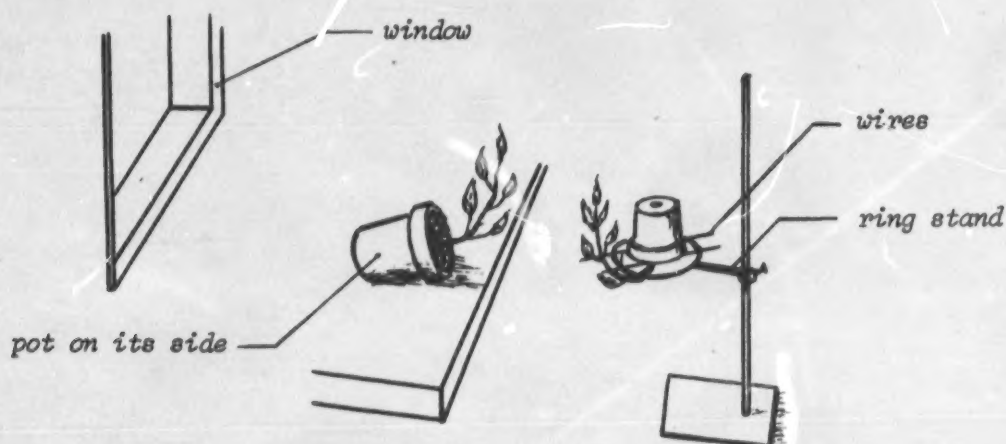
The thin membrane of the egg acts like a *semi-permeable membrane*, which allows small size molecules of water to pass through it, but not the large protein molecules in the egg. The water thus *migrates* from the outside of the egg to the inside, and in so doing pushes the liquid level up the tube. This liquid level difference, between that in the tube and that of the water in the glass, is called *osmotic pressure*.

PLANTS

GROWTH

16.6. HOW DOES GRAVITY AFFECT GROWTH?

- Materials:
1. Three small plants (identical in size and kind).
 2. A ring stand, two pieces of wire, cardboard.

Procedure:

1. Turn one flower pot with the small plant in it on its side and face the plant away from the window.
2. Place another flower pot with the small plant upside down on the ring stand supported on the two wires (tape cardboard securely over soil to prevent it from falling out), and place this stand below the window.
3. Place the third flower pot with plant normally in front of the window.
4. Observe plant growth in all three pots and compare.

Questions:

1. How did the plant on its side grow?
2. How did the upside down plant grow?
3. In what direction did all three plants grow?
4. Why did the plant on its side have to be faced away from the window?
5. How did the light from the window affect the growth?
6. Can we be absolutely sure that the light was not the cause of the plants to bend upwards?
7. How would we set up an experiment to investigate the influence of only gravity on the growth of a plant?

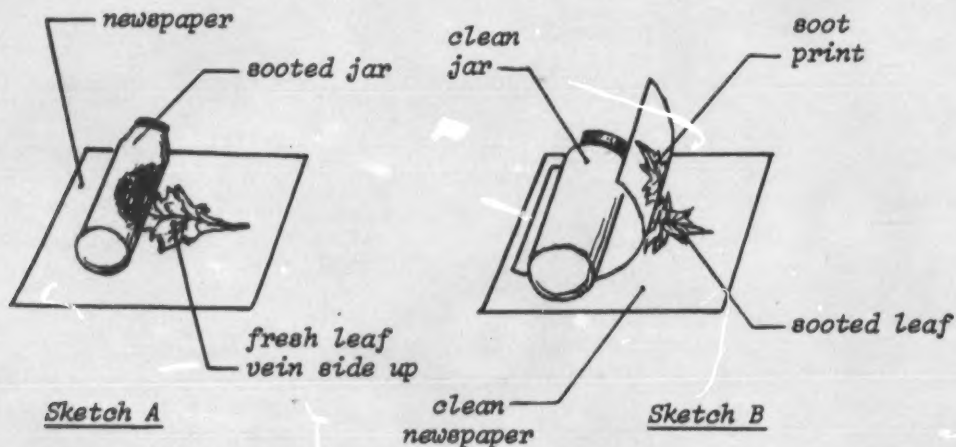
Explanation:

Plants in general, grow in the opposite direction of the growth of the roots, which is vertically upwards. They grow in the opposite direction of the gravity force. In nature, we can especially notice this when trees are growing on a steep hill or on the side of a mountain or cliff.

An experiment investigating the influence of gravity only would need to have all variables controlled, including the light variable, which has to come from all sides toward the plant. An open-ended question would be: How would a plant grow without gravity?

16.7. MAKE SOOT PRINTS OF LEAVES

- Materials:**
1. Two empty jars with tight lids.
 2. A candle, grease or Vaseline.
 3. Old newspaper, white blank paper, different leaves.

Procedure:

1. Cover the side of a smooth jar with a thin layer of grease or Vaseline. Fill the jar with cold water and screw the lid on tightly.
2. Cover the greased part of the jar with soot by holding it over a candle flame until it is evenly black.
3. Place a leaf with the vein side up on a newspaper and roll the soot-covered part of the jar over the leaf (see Sketch A).
4. Take the leaf and place it on a clean newspaper. Cover the leaf with a sheet of white paper and roll a clean jar over the paper and leaf. (see Sketch B).

Questions:

1. What is the purpose of the grease or Vaseline layer?
2. Why did we need cold water in the first jar?
3. Why was the leaf placed on the newspaper vein side up?
4. Which part of the leaf was covered with the black soot?
5. What type of leaves would give the best soot prints?

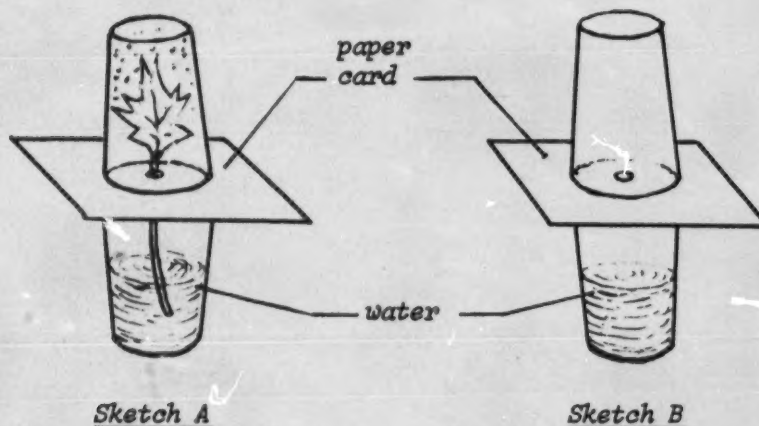
Explanation:

The jar with the grease and soot layer functioned as an ink roller to cover the veins of the leaf with a thin layer of soot. The leaf had to be placed vein side up, because the veins are bulging up (protruding) compared to the other parts of the leaf, and this makes it possible to color only the veins. When the white paper was placed on the sooted leaf, the veins only would give a black print on the paper. Leaves with strong bulging veins make the best soot prints.

PLANTS

RESPIRATION
LEAVES16.8. DO LEAVES GIVE OFF WATER?

- Materials:**
1. A large wide leaf or small plant.
 2. Four large drinking glasses (of the same size).
 3. Two paper cards.

**Procedure:**

1. Fill two of the glasses half way with water.
2. Cut a small hole in each of the two paper cards, such that the stem of the leaf or small plant would fit through it.
3. Cover the glasses with the paper cards, insert through one card the leaf stem, and cover with the inverted glasses (see sketch).
4. Observe and compare the inside of the upper glasses.

Questions:

1. In which glass did water droplets form?
2. Why did we need the set of glasses in Sketch B?
3. Where did the water droplets come from?
4. What kind of leaves would give off most water?
5. What variables would influence the amount of water transpired?
6. Would a whole plant covered in the same manner give off water too?

Explanation:

The water transpired from the leaf is in the form of water vapor. This latter condenses on the cold surface of the upper glass in Sketch A and thus water droplets are formed. In order to show that these droplets are indeed coming from the leaf rather than the water in the lower glass, the set-up in A is being compared with one without a leaf in it.

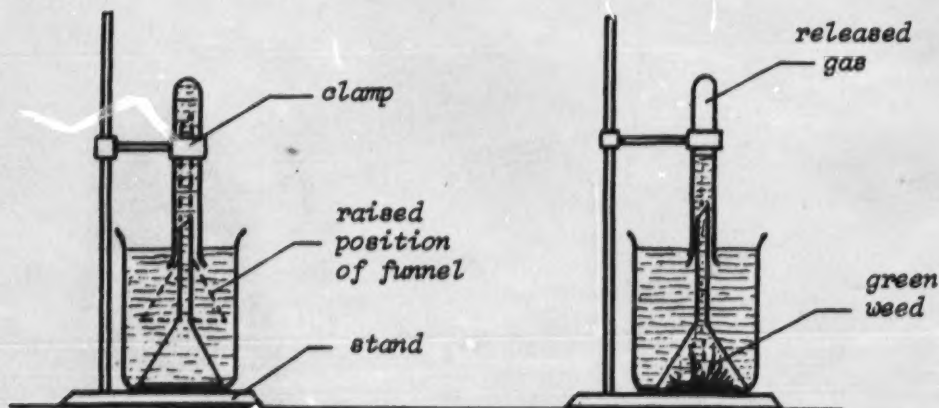
A small plant covered in the same way with a card around the stem in the pot and an inverted glass over the whole plant, would give the same results.

Variables that would influence the amount of water transpired are: type of leaf, surface area of the leaf, age of leaf, etc.

PLANTS

LEAVES
RESPIRATION16.9. WHAT DO GREEN LEAVES BREATHE OUT? (I)

- Materials:**
1. Green weed & wood splint.
 2. A large beaker, a funnel, a test tube.
 3. A stand and clamp.

Procedure:

1. Fill the beaker with water, immerse the funnel and the test tube in the water, and set the apparatus up as in Sketch A.
2. Raise the funnel and place some green weed under it.
3. Leave the apparatus in strong sunlight or under a spotlight and observe the bubbles given off by the leaves.
4. After collecting almost a full test tube of gas, test it with a glowing wood splint.

Questions:

1. What gas is collected from the test tube?
2. What did the glowing wood splint do when lowered in the test tube?
3. What made the water in the test tube stand so much higher than the water level in the beaker? (Sketch A).

Explanation:

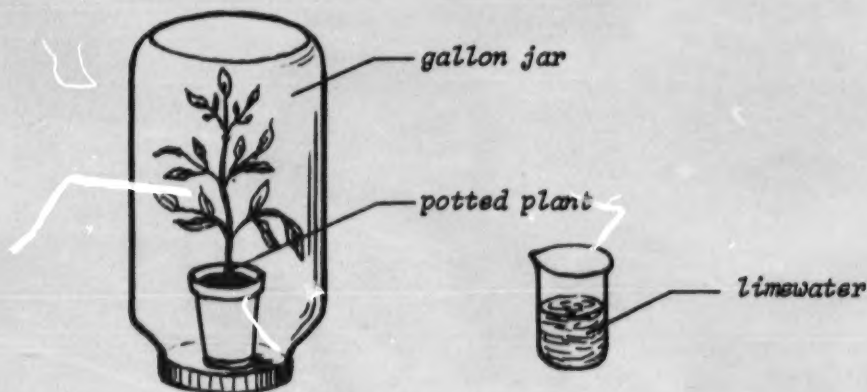
The green in the leaves, which is chlorophyll, produces sugar and cellulose and starch in the plant. During this process of sugar production carbon dioxide and water, oxygen is released. This only occurs during day-time when the sunlight is shining on it. The purpose of the funnel is to bring all the bubbles released by the weed together under the test tube. As the glowing splint flares up into the bright flame in the gas, it indicates that the gas is oxygen.

The fact that plants give off oxygen during the day time makes having them in the living room a good thing. The air is enriched with oxygen and it is therefore healthy to have plants in the room.

PLANTS

LEAVES
RESPIRATION16.10. WHAT DO GREEN LEAVES BREATHE OUT? (II)

- Materials:
1. A wide-mouthed gallon jar & lid.
 2. A small potted plant.
 3. Limewater (calcium hydroxide).

Procedure:

1. Place the potted plant on the inverted lid of the jar and invert the large jar over the whole plant, and turn the jar into the lid.
2. Leave the jar and plant in a complete dark place for several hours.
3. Turn the lid loose and remove the plant carefully.
4. Turn the jar right side up and pour about 100 ml of limewater in it, screw the lid on, and shake.
5. Observe the limewater (turning milky),

Questions:

1. What gas was released by the leaves in the dark?
2. What reaction did the gas give with the limewater?
3. How would this gas react with a glowing wooden splint?
4. With many plants in a room, how would the composition of the air change from day time to night time?
5. Why is it better to take plants out of the bedroom at night?

Explanation:

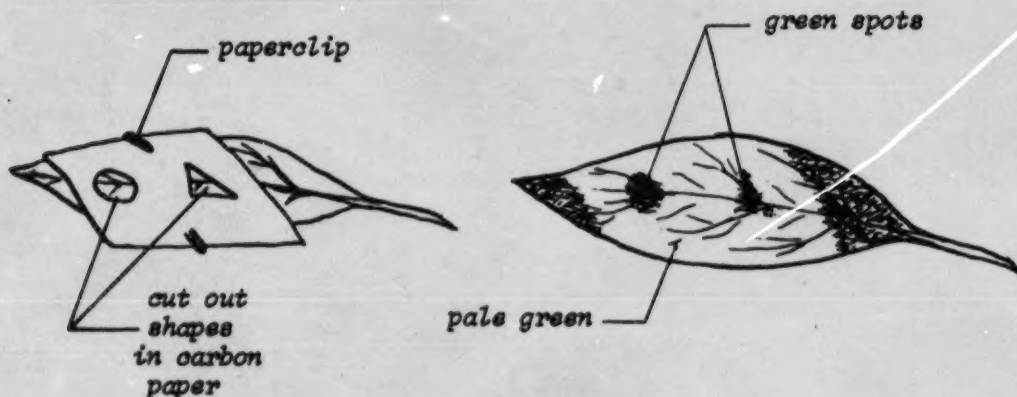
Plants give off carbon dioxide when placed in the dark. This is indicated by the reaction with the limewater (calcium hydroxide): $\text{CO}_2 + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$, forming calcium carbonate which is insoluble in water. This is the cause for the limewater to turn milky.

When this gas produced in the dark is tested with the glowing splint, it would extinguish the glow completely, as carbon dioxide does not support the burning process. With many plants in a room, the air would be rich in oxygen content during the day and high in carbon dioxide content at night. This is why it is better to take plants out of the bedroom at night time.

PLANTS

LEAVES
PHOTOSYNTHESIS16.11. HOW IS THE GREEN IN THE LEAVES PRODUCED?

- Materials:**
1. A plant with large wide leaves.
 2. Carbon paper or black construction paper.
 3. Paper clips or masking tape.

**Procedure:**

1. Cut out several patterns (circle, square, triangle) in several pieces of the carbon paper.
2. Cover three or more leaves as much as possible with the cut out carbon paper by attaching it to the leaves with the paper clip or masking tape.
3. Cover some leaves halfway with carbon paper close to the stem (or any other pattern of covering) and leave it attached for 2 or 3 days.
4. After leaving the black paper against the leaves for several days, remove the attached paper and observe the leaves.

Questions:

1. How did the covered areas of the leaves compare to the uncovered ones?
2. Do plants need sunshine to produce the green color?
3. What is the green color in the plant leaves called?
4. What is the process of production of the green color called?
5. What is the function of the chlorophyll in plant leaves?

Explanation:

The covered areas of the leaves will become much paler. The longer it stays covered, the paler the color, because no sunshine is penetrating the green pigment that enables every plant that possess it to combine water and carbon dioxide from the air, to form sugar. This process in which sunshine is an essential ingredient is called *photosynthesis*. It is the sugar in the plants which gives animals and man the energy when it is consumed by them.

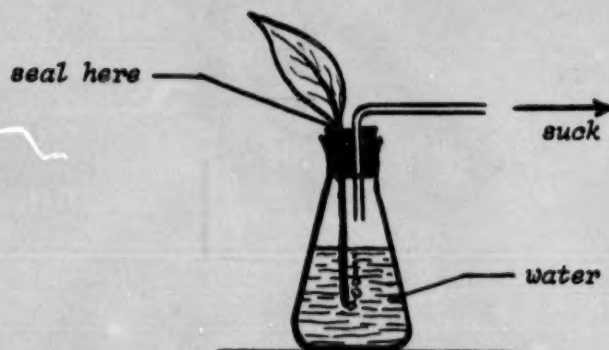
The chlorophyll also produces cellulose, a much larger molecule than sugar, which is the basic building material in plants. Thus, without sunshine the leaves do not produce chlorophyll, no cellulose, and therefore plants do not grow.

PLANTS

LEAVES

16.12. CAN AIR ENTER THROUGH A LEAF?

- Materials:**
1. A leaf with a long stem.
 2. A small Erlenmeyer flask.
 3. A 2-hole stopper that fits in the flask.
 4. A bent glass tube.
 5. A candle + matches.

**Procedure:**

1. Stick the leaf stem through one of the holes in the 2-hole stopper and seal it with dripping wax from a lit candle.
2. Insert the bent glass tube in the other hole of the stopper.
3. Fill the Erlenmeyer flask with water to such a level that only the leaf stem immerses in it and not the glass tube.
4. Place the stopper tightly into the flask and suck through the side tube.
5. Observe air bubbles issuing from the end of the stalk.

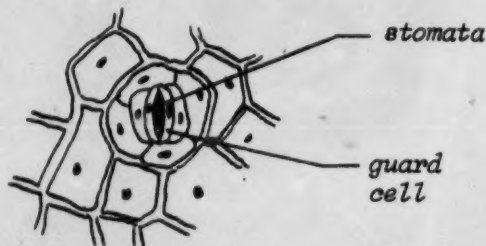
Questions:

1. Why does the stem have to be sealed in the stopper?
2. What would happen if the glass tube were also immersed in the water?
3. Are the leaf and stem actually that porous that air can go through them?
4. What is the actual structure of the leaves?

Explanation:

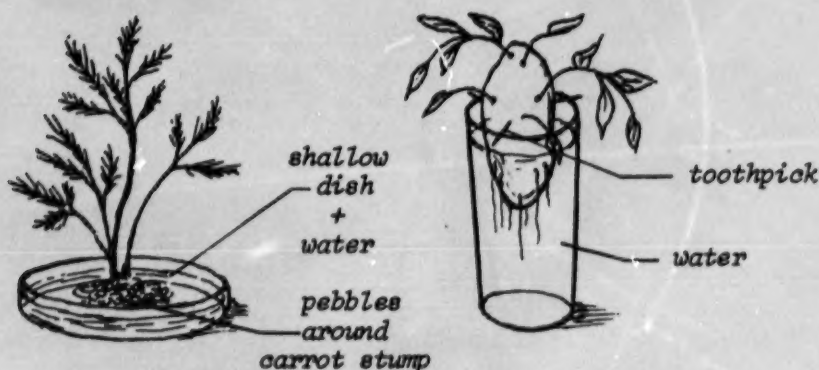
The sucking through the side tube lowered the pressure inside the flask, causing the atmospheric air to seep through the leaf and the stalk resulting in the bubbles issuing from the end of the stalk.

When looking through a microscope and examining the underside of leaves, we can see breathing pores or stomata with two little guard cells on each side of the stomata. (see sketch on right).



16.13. GROW SWEET POTATO AND CARROT LEAVES

- Materials:**
1. A sweet potato.
 2. A drinking glass or beaker.
 3. A shallow dish (Petrie dish)
 4. Three toothpicks or thin nails.
 5. Some pebbles or gravel.

**Procedure:**

1. Hold the sweet potato with the eyes or buds on the top side.
2. Immerse the potato about one third in the water contained in the drinking glass.
3. Support the potato by sticking three toothpicks or nails into its side and resting it on the glass rim.
4. Remove the old leaves from the top of the carrot and cut off all of the lower part except about 5 cm.
5. Place this stump in water in the shallow dish and support with pebbles or gravel around it.
6. Put sweet potato and carrot in a warm and sunny place and observe foliage growth.

Questions:

1. Where did the potato or carrot plant get its food from?
2. How does the potato leaf differ from that of the carrot?
3. Would these plants develop new potatoes or carrots?
4. What other plants could be grown this way?

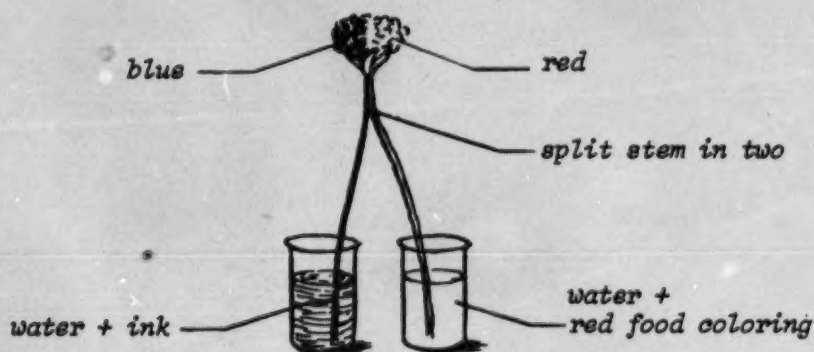
Explanation:

The potato, like the carrot, beet or turnip, contains much stored food. When placed in water, it is enough to produce thick foliage. When this food supply is depleted, it needs to be placed in soil and receive other nutrients in order to produce new potatoes and carrots. When a pineapple is cut about 5 cm below the base of the leaves and placed in water, the leaves will continue to grow for quite some time drawing nutrients from its stored food in the pineapple itself.

PLANT KINGDOM

OSMOSIS
CAPILLARY ACTION16.14. MAKE A RED-BLUE CARNATION

- Materials:**
1. A white carnation (with a long stem).
 2. Red food coloring & blue ink.
 3. Two small beakers or cups.

Procedure:

1. Take the carnation and cut the stem to leave about 15 cm on the flower.
2. Split the stem in half, starting a cut with a knife and further splitting it along the fibres (without breaking them!)
3. Fill the two small beakers with water, color one red with the food coloring and the other blue with the ink.
4. Place each half of the stem in each beaker and observe the flower.

Questions:

1. What was the purpose of splitting the stem in half?
2. Did the whole white carnation get colored?
3. Is it possible to color only part of the flower and leave another part white?
4. How would the stem have to be split to obtain three colors in the flower, say red, blue and white?
5. What force is pulling the colored solution up the stem?
6. Would leaves be able to be colored the same way?

Explanation:

The colored water is drawn up the stem of the carnation by osmosis and capillary action. The water molecules diffuse through the fibre membranes from a less to a larger concentration of plant sap (osmosis). The fibres are so tiny that the adhesive force of the water molecules to the fibre walls becomes very great. This capillary force in combination with the osmotic pressure sucks the water up the flower.

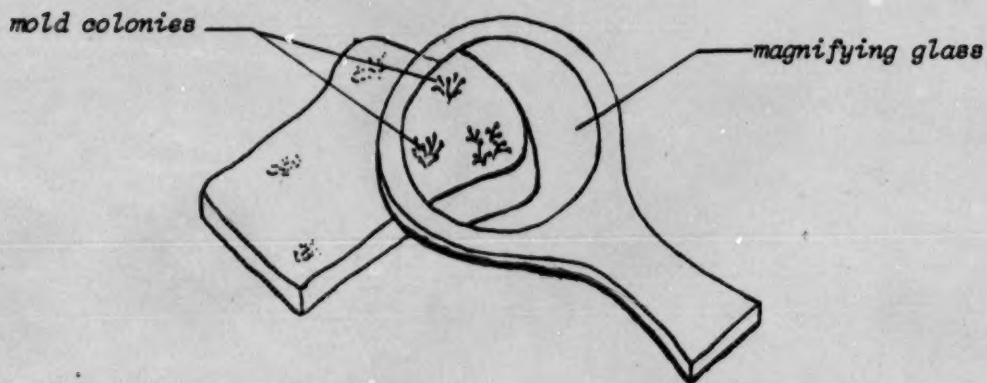
When the stem is split three ways, it is very likely that the flower will be three way colored. This shows that the fibres must somehow run all the way from the stem to the petals of the flowers.

PLANTS

REPRODUCTION

16.15. HOW DO MOLDS REPRODUCE?

- Materials:**
1. Eight slices of bread.
 2. Saran Wrap or cellophane.
 3. A magnifying glass.
 4. A shallow dish (saucer or Petrie dish).

**Procedure:**

1. Take two slices of bread. Wrap one slice in the Saran Wrap and seal off from the air and leave the other one open to the air.
2. Take two other slices: place one in a dry spot and place the other over a shallow dish filled with water.
3. Expose two other slices: one to a strong light (flood light) and keep the other in a dark place.
4. Expose two more slices: keep one in a warm dark place and the other in a cold dark place.
5. Observe the surface of the bread slices daily through the magnifying glass and record the changes. Make a note of the mold colonies, the number of them and their growth rate.

Questions:

1. What variable was manipulated in step 1 of the procedure?
2. What variable did I choose to change in Steps 2, 3, and 4?
3. What was the responding variable in all four cases?
4. In which case did the mold develop best?
5. How should bread be stored to keep it mold free?
6. What other types of food will develop molds if kept over a longer period of time?

Explanation:

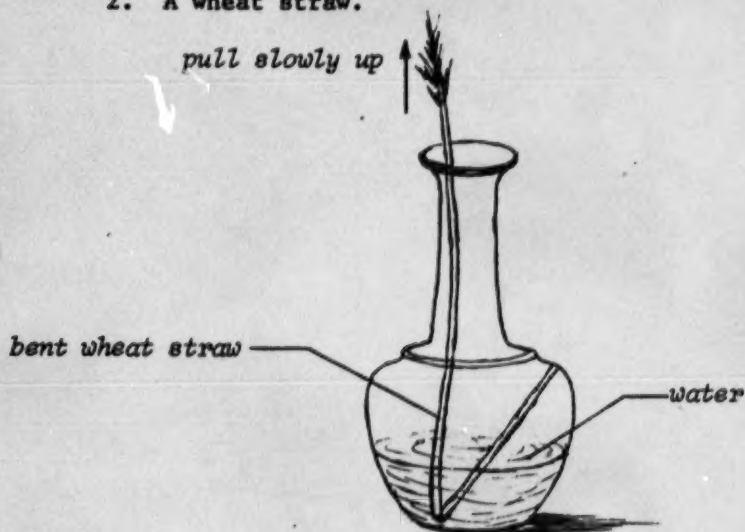
Mold grows best in moist, dark and warm places. Dry, light and cold conditions will discourage the growth of molds. Under step 1 of the procedure the presence or absence of air was the manipulated variable, under step 2 moisture, step 3 the presence of light, and step 4 the temperature. Other foods that will develop molds are: cheese, jam, left over food or meats, etc.

PLANTS

TENSILE STRENGTH

16.16. PICK UP A CARAFE WITH A STRAW

- Materials:
1. A wine carafe (or other long necked bottle).
 2. A wheat straw.

Procedure:

1. Fill the carafe half full with water.
2. Bend the straw such that the short bent part will fit in the wider part of the bottle (see sketch).
3. Lower the straw in the bottle and allow the bent part of the straw to open up.
4. Now pull the carafe slowly upwards by holding the protruding straw.

Questions:

1. Why did the straw not break?
2. What force was exerted on the straw?
3. What will happen to the straw if we wait a while before pulling the carafe up?
4. What will water do when plant material is soaked in it?
5. Where or in what direction lies the greatest strength of a wheat stalk?
6. What implications can we see in living plants?

Explanation:

It is especially critical where the fold in the straw is made. It should be folded at a spot such that the short part will just fit in the wider part of the carafe. By pulling the straw up, the bottom part of the straw should press on the side, and the top part should hook on the rather horizontal part of the bottle. The stress in the straw would be mostly lengthwise and as the tissue of the wheat stalk is made up of tubular capillaries and vessels, it can withstand a rather high stress. Over time the water will penetrate into the straw tissue and weaken it. This will be more so the case when a dry straw is used rather than a fresh one.

CHAPTER 17

WHAT CAN WE LEARN ABOUT THE HUMAN BODY ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

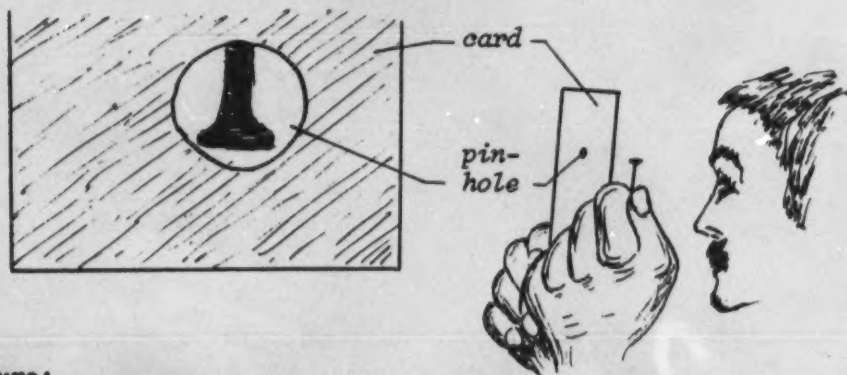
- a. recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. explain in their own words which of the sub-concepts is determining the course of an event;
- c. distinguish true from false statements concerning each one of the sub-concepts;
- d. identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

- All objects seen by the human eye cast an upside down image on the retina, which is interpreted by the brain as right side up.
- People need two eyes to see objects in three dimensions.
- The majority of people are right-sighted.
- The cones in the human eye pair the following colors: red-green, yellow-blue, and white-black.
- Illusion is an interpretation of the brain, which deviates from the true perception by the eyes.
- The number of nerve endings is larger at the finger tips compared to other parts of the human body.
- The number of heartbeats increases with intensity of exercise.
- Exhaled air contains more carbon dioxide than inhaled air.
- Enzymes in saliva break down starch into sugar.
- Food is pushed down the esophagus by peristaltic action.

17.1. THE REVERSED IMAGE

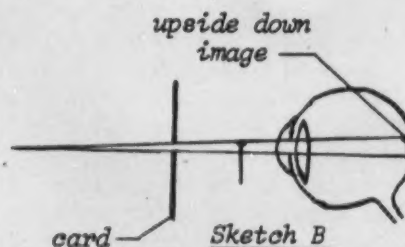
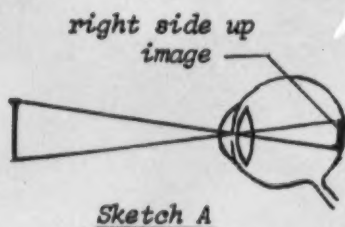
- Materials:**
1. A paper card (3x5" / 8x12 cm)
 2. A regular sewing straight pin.

**Procedure:**

1. Pierce a hole with the pin in the center of the card.
2. Hold the card about 10 cm in front of one eye and hold the pin rightside up between the card and the eye (view the pin against a window or light): an upside down image of the pin will be observed.
3. Now hold the hole in the card about 3 cm from the eye and hold your eyelid almost closed: upside down images of the eye lashes will be seen!

Questions:

1. Why do we see an upside down image of the pin?
2. Why did the image of the pin disappear from in front of the card?
3. What did the eye actually focus on?
4. What was the purpose of the pinhole?
5. Why do we have to view the pin against a window or a light?

Explanation:

All objects will cast an upside down image onto the retina when the human eye is focussed on them, which the brain interprets as rightside up (see Sketch A).

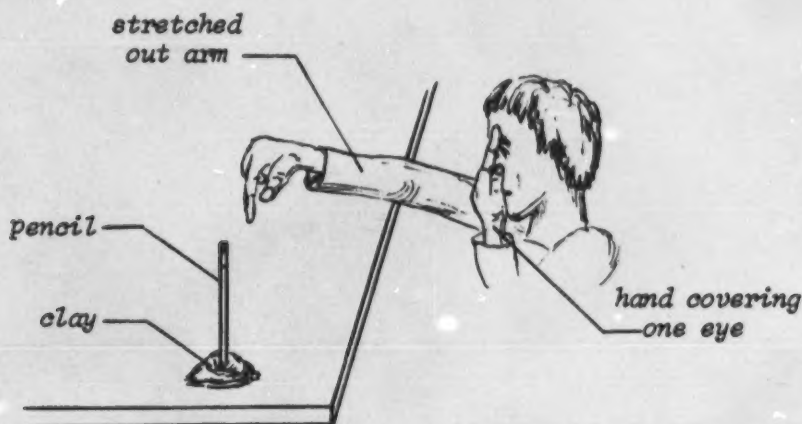
The small hole in the card serves as a slit to admit the light, forming a small bundle of light that enters the eye (see Sketch B). This small light beam casts a shadow of the pin upside down onto the retina (actually rightside up, but interpreted by the brain as upside down).

HUMAN BIOLOGY

EYE SIGHT

17.2. WHY DO WE NEED TWO EYES?

Materials: 1. A pencil & a piece of molding clay.

Procedure:

1. Place the pencil vertically in a piece of clay on the table top.
2. Let the students one by one try the following, while the rest of the class observes:

Approach the pencil from the side about 3 - 4 meters away with one eye (cover the other eye with your hand). Hold the other hand stretched out and without hesitation, point down with the index finger and try to touch the pencil. Repeat again. Now repeat with both eyes open.

Questions:

1. Why did most students miss touching the pencil end?
2. After a student tried to do the trick several times, why did he/she get better at touching the pencil?
3. Do you think it would be easier to do by approaching the pencil slowly?
4. What happens when the experiment is done with both eyes open?
5. What do you lack when just one eye is used?
6. Why must the pencil be touched without hesitation?
7. If we see differently with each eye, why don't we see two images when both eyes are open?

Explanation:

Most people will not be able to touch the pencil on the first try, because they do not see with one eye, how far in front of them the pencil is located. *One cannot judge depth and distance as well with one eye as with two.* With one eye, one sees everything in the same plane (as in a picture). In other words, everything becomes two dimensional rather than three dimensional.

With a little practice one will get better at judging distances with only one eye.

17.3. DO WE REALLY USE BOTH EYES?

- Materials:**
1. Two cardboard cylinders (about 30 cm long)--the core of wrapping paper or paper towel suits fine.
 2. Two different pages of a newspaper.

**Procedure:**

1. Place the two sheets of newspaper on the desk in front of you.
2. Hold the cardboard tubes in front of each of your eyes, such that you can look at one sheet with one eye and at the other sheet with the other eye.
3. Keep both eyes open at all times--can you read both pages at the same time? Which do you read more easily?

Questions:

1. Which page do you read more readily?
2. Do you have to shut the other eye when reading one of the pages?
3. Why is it not possible to read both pages at the same time?
4. What does the preference of using one of your eyes indicate?
5. In what instances do we have to use just one eye?

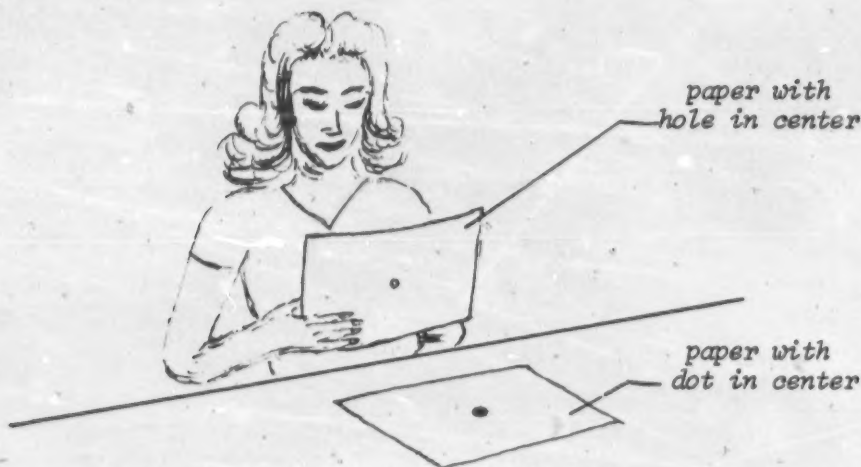
Explanation:

We shall not be able to read both pages simultaneously, because we can only focus on one thing at a time. Although both eyes remain open, we can focus on one page or the other at will. It takes a simple act of will for one eye to see properly and for the other to stare blankly. It may thus be argued that we often make use of only one eye, even when we keep the other wide open. Evidently we do not have to cover one eye, either by holding a hand in front or closing the eye lid, when the use of only one eye is required, like when aiming a gun or looking through a microscope, or any other instrument requiring the use of only one eye.

People, however, do prefer to use either the left or the right eye when they have the option, indicating that there are *left-sighted* or *right-sighted* people, just as there are left or right-handed people. Which group do you belong to?

17.4. ARE YOU LEFT- OR RIGHT-SIGHTED?

- Materials:
1. Two blank sheets of white paper.
 2. A pencil.

Procedure:

1. Pierce a hole in the center of one sheet of paper with a pencil.
2. Draw a black dot in the center of the other sheet of paper the size of a penny, and place this about 40 cm in front of you on the table.
3. With both eyes open, hold the sheet with the hole between your face and the sheet with the dot, and move the first sheet about until the black dot can be seen through the hole.
4. While holding this sheet steady (while seeing the dot), close first your left eye and then your right. When does the dot disappear?

Questions:

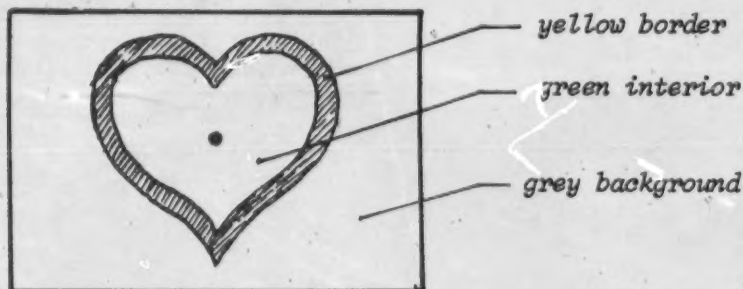
1. Does the dot disappear after closing your left or your right eye?
2. If the dot disappears when closing your left eye, are you left-sighted or right-sighted?
3. If the dot disappears when closing your right eye, are you left-sighted or right-sighted?
4. After determining that you are right-sighted, does it make any difference whether you are closing your left eye or not in looking at the dot?

Explanation:

For most people the dot will disappear when closing the right eye. This indicates that most people are *right-sighted*. It means that most people prefer to use their right eye over the left, if they are confronted with the option of using only one. In this case it means that those people can see the dot with both eyes open or with only the right eye open, but not with only the left eye. In other words, when both eyes are open, the left eye does no work. There is probably a connection between this phenomenon and the right-handedness of most people, although it would be hard to say which is the cause and which the effect.

17.5. HOW DO WE PERCEIVE COLOR?

- Materials:**
1. A drawing of a heart-shaped figure (or other shape) having a yellow border, a green interior, and a small black dot in the center (on a double page size paper).
 2. A plain double page size paper with a small black dot in the center of it.

**Procedure:**

1. Let the students one by one stare at the colored heart for twenty seconds without blinking their eyes, focussing on the black dot.
2. Let them immediately after look at the plain piece of white paper, focussing on the black dot.
3. Ask the students to report what they see.

Questions:

1. What color is the interior of the heart? The border?
2. What did you see when looking at the plain white paper?
3. What were the colors as compared to the first heart you viewed?
4. Why do you think was the second heart not the same as the first one?
5. Was there any heart drawn on the blank sheet of paper?
6. What colors does the human brain pair together?

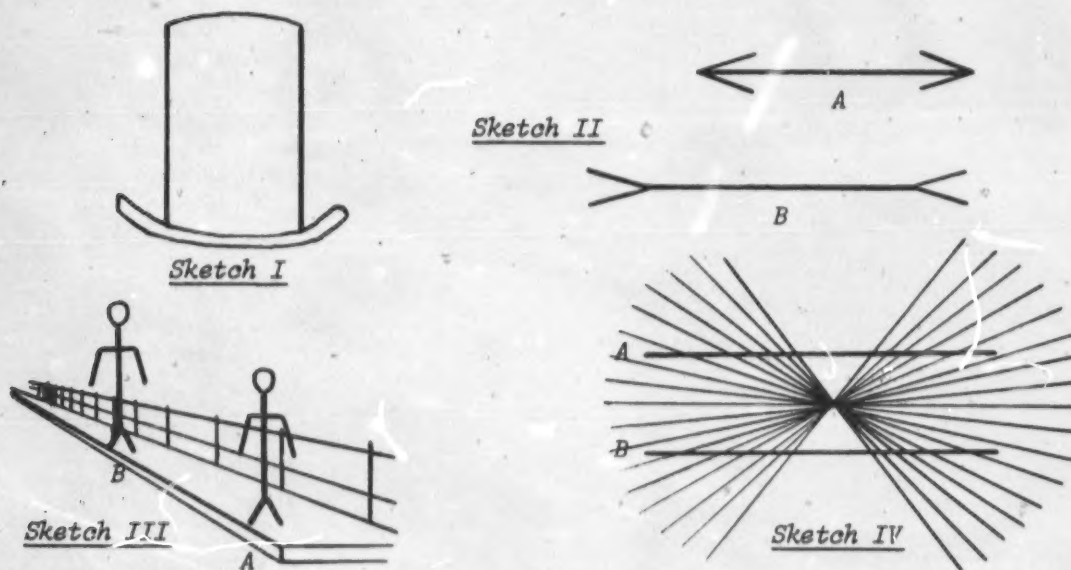
Explanation:

There appears to be an unusual relationship between the eye and the brain in the human being. There is a relationship among four primary colors: red, green, blue, and yellow. As the retina absorbs light, coders farther back in the eye discriminate between the colors. The black-white coders can send a combined grey image, but one coder relays signals for green or red, and another coder for blue or yellow. These colors oppose each other and will not mix. *Steady exposure to any color tends to weaken the brain's response: a bleaching effect makes the color fade or makes it grey.* After staring at the yellow and green heart, a clear after-image was seen of a red heart bordered in blue. There is a temporary switching of signals to the brain. Since red and green share a single coding mechanism, as do yellow and blue, withdrawal of the color stimulus shuts down one part of the mechanism and triggers the other part for a moment or two.

The cones in the human eye pair the following colors: red-green, yellow-blue, and white-black.

17.6. WHAT GIVES US THE ILLUSION?

Materials: 1. Rulers (30 cm) & pictures or drawings of sketches below:

Procedure:

1. Let the students look at the pictures and ask the questions corresponding with each of the sketches.
2. Let the students measure or place the ruler along the lines.

Questions:

1. How tall is the top hat compared to its width? (Sketch I)
2. Which of the two lines A or B is longer? (Sketch II)
3. Which of the two puppets is taller? (Sketch III)
4. Are the two lines A and B straight or curved? (Sketch IV)
5. What gave us the illusion in each of the sketches?

Explanation:

In Sketch I of the top hat, people do not take the brim of the hat into account, and this is why the hat looks taller than it is wide. In the second sketch, people tend to look at the picture as a whole: line plus arrows at the end, and then line B looks longer. In picture III, the two puppets are seen in a three dimensional environment, where puppet B looks farther away than puppet A, and thus puppet B seems much taller. In Sketch IV it is the environment again that gives us the illusion that the two heavy drawn lines are curved.

By measuring each of the dimensions and by placing the ruler against the lines (for Sketch IV), we soon see that the dimensions of the hat, the two lines (in Sketch II), and the two puppets are exactly the same, and also that the two lines (in Sketch IV) are straight and running parallel to each other.

HUMAN BIOLOGY

EYE SIGHT
PERCEPTION17.7. SEE A HOLE IN YOUR HAND

Materials: 1. A cardboard cylinder (the core of paper towel or wrapping paper serves well) about 30 cm long (for each pair of students)

Procedure:

1. Pass the cardboard cylinders to the students (one for each pair or let two or three cylinders float around).
2. Demonstrate how to hold the cylinder and hand:
Hold the cylinder with the right hand in front of the right eye, hold the left hand next to the cylinder close to the end of it, keep both eyes open and look (focus) at a distant point.
3. Now close each eye one at a time; open both eyes again.
Do you see the hole in your left hand?

Questions:

1. What did your left eye see (when the right was closed)?
2. What did your right eye see (when the left was closed)?
3. How did you come to see a hole in your left hand?
4. What do you have to do to see a hole in your right hand?
5. What can you infer from this, that the brain is doing with the vision or perception of each individual eye?

Explanation:

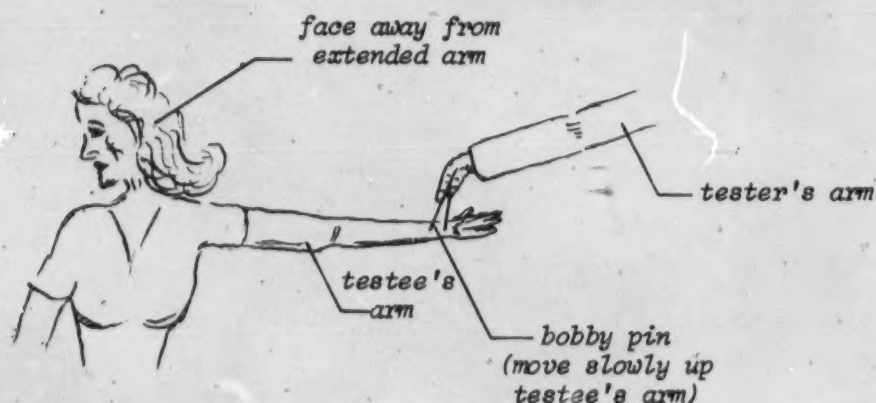
By focussing at a distant point, the left eye in front of which the left hand is held, does register an image of the hand, but it is more the image of the right eye which is registered in the brain (because the eyes were focussed at a far point through the cylinder). When both eyes are open, it is the image of both eyes that are registered and combined by the brain. This is the reason why a hole is seen in the left hand. By switching the roles of the hands, it is possible to see a hole in the right hand.

HUMAN BIOLOGY

NERVOUS SYSTEM

17.8. HOW MANY POINTS ARE TOUCHING?

Materials: 1. A bobby pin (hair pin) for each pair of students.

Procedure:

1. Let students work in pairs: one be the testee and the other the tester. The latter holding the pin.
2. Instruct the tester to spread the two tips of the bobby pin and place it on the testee's finger, hand, and arm, moving slowly up the arm starting from the middle finger, touching the skin randomly either with one or two tips.
3. The testee should look away from the touched arm (see sketch) and tell the tester how many tips he/she feels (without looking at the pin).
4. The tester should keep track of the number of mistakes made at the different parts of the arm. (Let tester and testee change roles).

Questions:

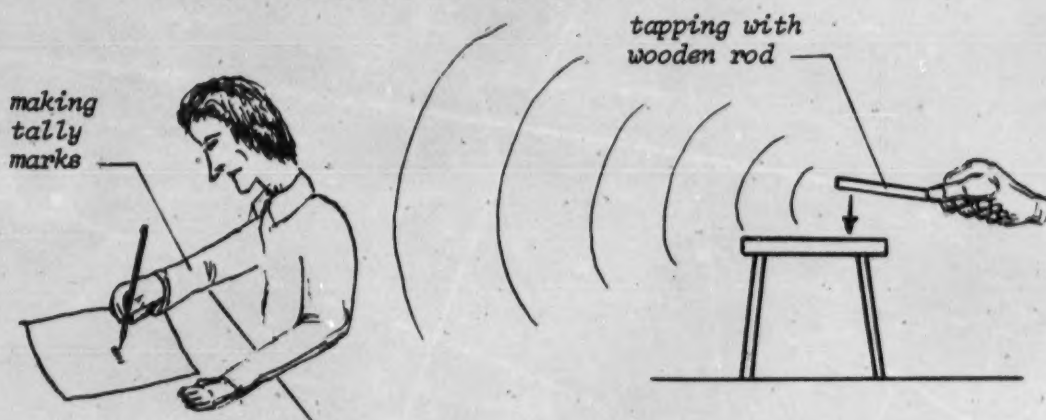
1. Where was it easier to tell how many tips were touching?
2. Why did we make more mistakes, the higher up the arm the pin was touched to the skin?
3. What makes our touch sense more sensitive?
4. Where would a cut in the skin hurt most?

• Explanation:

This activity demonstrates the distribution of the *nerve endings* in the human body, in our case from the fingertips to the shoulder. It is increasingly difficult to tell without looking how many tips are actually touching the skin, the higher up the arm the pin is placed. This is caused by the fact that there are many more nerve endings in the fingertips and hands compared to the upper arm. It would therefore be more painful to experience a cut in the skin closer to the fingertips than higher up the arm. For this same reason, our sense of touch is most sensitive at our fingertips compared to other parts of the body.

17.9. THE STIMULUS-RESPONSE ACTION

- Materials:**
1. A wooden rod or block (a ruler would do).
 2. Paper and pencil for each student.

**Procedure:**

1. Stand in the rear of the class behind the students.
2. Instruct the students to make a tally mark every time you say "write".
3. Strike a desk with the wooden rod and simultaneously say "write" for a total of 20 times with 2 seconds intervals.
4. Continue striking the desk, but stop saying "write" until everyone has stopped writing.
5. Have the students count their tally marks.
6. Tell the students that you said "write" exactly 20 times.

Questions:

1. Why did most students make more than 20 tallies?
2. What was the stimulus and what was the response?
3. Why did I pair the strikes with the saying of "write"?
4. What was the purpose of the taps with the wooden rod?
5. Why did everyone stop writing eventually?

Explanation:

When a *response-eliciting stimulus* (the saying of "write") is paired with a *neutral stimulus* (taps with the wooden rod), the student becomes *conditioned to the neutral stimulus*, so that the neutral stimulus will elicit the response, even when it is presented alone. The conditioning will become extinguished after a certain time, if the presentation of the *conditioned stimulus* (tapping noise) is continued without pairing with the *unconditioned stimulus* (the saying of "write").

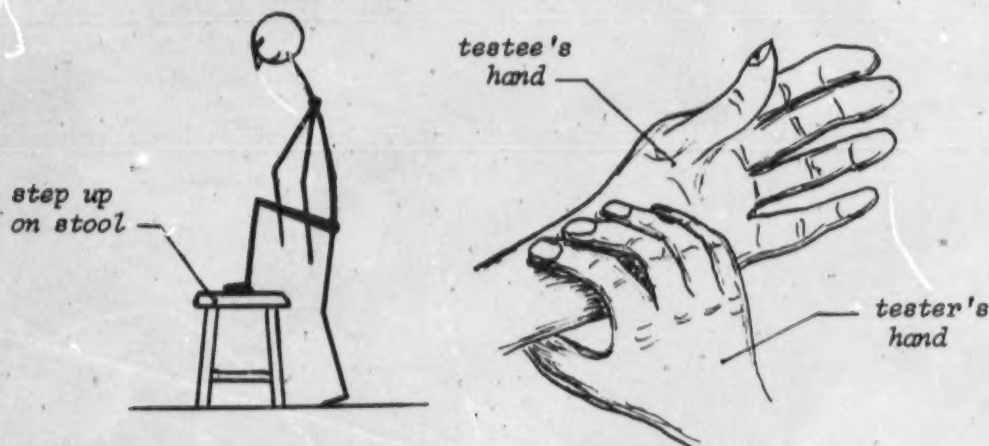
This conditioning of the human being to neutral stimuli occurs in daily life for example, when the preparation of food or a meal is constantly accompanied by the clatter of kitchen utensils; hearing only the clatter will stimulate the feeling of hunger or might even stimulate the production of saliva in the salivary glands (drooling).

HUMAN BIOLOGY

CIRCULATORY SYSTEM

17.10. HOW FAST DOES YOUR HEART BEAT?

- Materials:**
1. Low step stools.
 2. A stopwatch or a watch with a second hand.

**Procedure:**

1. Let students work in pairs: one being the tester and the other the testee.
2. Instruct the tester to count the number of heartbeats of the testee by placing his fingers on the testee's wrist, and counting the pulses within 10 seconds (and multiply this by 6).
3. Now let the testee step up and down the stool 10 times, and immediately after that let the tester take the testee's pulse (repeat point 2).
4. The number of steps up and down the stool can now be increased to 20 and 30, immediately followed by a pulse count.
5. Let the tester and testee change roles.

Questions:

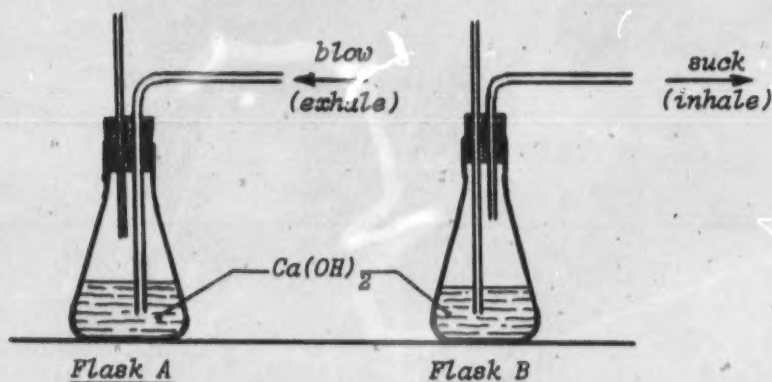
1. What was the pulse before the steps up and down the stool?
2. What was the pulse after 10, 20, and 30 steps up and down the stool?
3. What made the heart beat faster after the exercise?
4. What did the muscles need to do all that work?

Explanation:

The pulse or heartbeat is caused by the *blood pressure impact on the arteries* as the heart muscles contract. It can be felt by placing a finger on the *radial artery* at the wrist. By doing vigorous exercise, like the steps up and down the stool, the leg muscles need more oxygen and thus more blood to carry this oxygen. The heartbeat thus automatically speeds up to pump more blood to the working muscles, from around 72 beats per minute to more than 120. Within three minutes this speeded pulse should return to the normal 72. With increasing number of steps up on the stool, an increase in the pulse should be observed in the testee. Some deviations from these values may be normal for certain individuals.

17.11. WHICH CONTAINS MORE CARBON DIOXIDE?

- Materials:**
1. Two Erlenmeyer flasks.
 2. Two sets of glass tubing in 2-hole stoppers (see sketch).
 3. Saturated lime water (calcium hydroxide).

**Procedure:**

1. Make a saturated solution of calcium hydroxide by adding small amounts of the solid powder, a little at a time to warm water while stirring, until no more solid dissolves.
2. Fill each flask half full with the lime water and cover them with the two-hole rubber stoppers (and fitted glass tubing).
3. Suck through the tube which ends above the water surface in flask A and exhale through the tube that extends into the liquid in flask B (see sketch).

Questions:

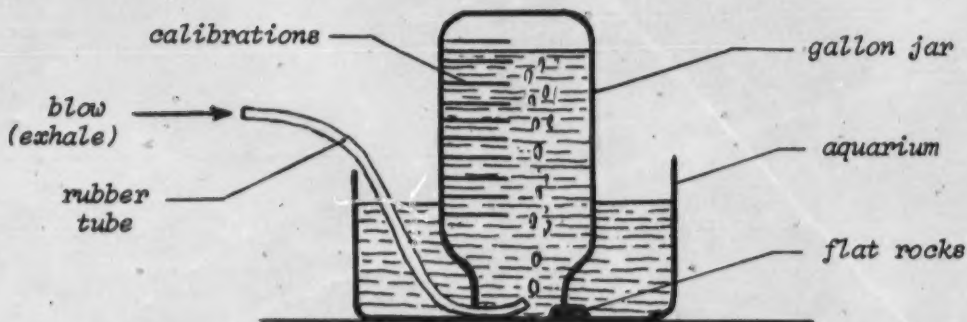
1. Which of the two flasks is getting milky first?
2. What gas is actually led through the liquid in flask A?
3. What does it indicate if the liquid turns milky?
4. What chemical reaction is taking place?
5. Will flask A eventually also turn milky if the sucking is continued?
6. What will the liquid in flask B eventually do if the blowing through it is continued?
7. Which of the two, inhaled or exhaled air, contains more CO_2 ?

Explanation:

By sucking through the tube in flask A, atmospheric air is led through the saturated calcium hydroxide solution (this air is the same as the air we inhale). By blowing through the tube in flask B, exhaled air is led through the liquid, which turns milky sooner than that in flask A. This indicates that there is more CO_2 present in exhaled air. The reaction is as follows: $\text{CO}_2 + \text{Ca(OH)}_2 = \text{CaCO}_3 + \text{H}_2\text{O}$, in which the calcium carbonate precipitates out and makes the solution appear milky. The CO_2 in the air will eventually turn the liquid in flask A also milky, and when the blowing is continued in flask B, the reaction: $\text{CO}_2 + \text{CaCO}_3 + \text{H}_2\text{O} = \text{Ca(HCO}_3)_2$ will turn the liquid clear again (Ca-bicarbonate is soluble in water).

17.12. MEASURE THE CAPACITY OF YOUR LUNGS

- Materials:**
1. A large glass jar (pickle gallon jar).
 2. An unused aquarium (or other transparent container).
 3. A length of rubber tubing (about 40 cm long).
 4. A 1 liter measuring cylinder (or other liter container).

**Procedure:**

1. Calibrate the large jar by filling it with water, liter by liter, and marking the water level with a marker or masking tape.
2. Fill the gallon jar completely full and the aquarium 3/4 full with water.
3. Place three flat stones of the same thickness (or other heavy objects) on the bottom of the aquarium, and invert the gallon jar into the water-filled aquarium so that it rests on the three stones.
4. Insert one end of the rubber tubing under the mouth of the gallon jar and let the other end hang over the rim of the aquarium.
5. Let one student hold the inverted jar steady and another student, whose lung capacity is to be measured, exhale through the tube after inhaling as deeply as he/she can.
6. Measure volume of exhaled air in jar.

Questions:

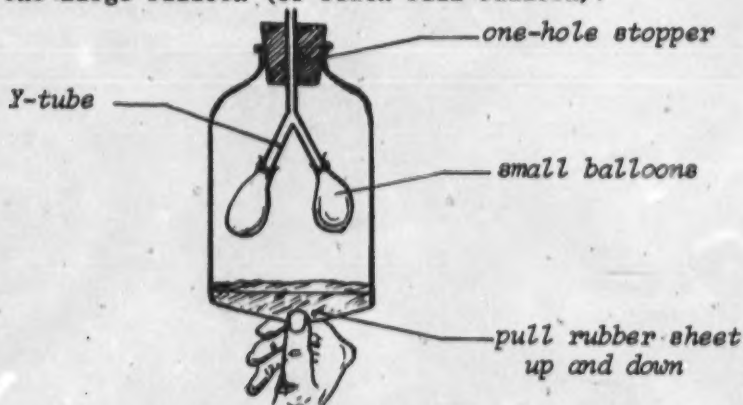
1. What made the water stay up in the inverted jar?
2. Why did the student have to inhale as deeply as possible before inhaling?
3. In exhaling, what does the student have to do in order to obtain a true measure of his/her total lung capacity?

Explanation:

By inhaling as deeply as we can, we are actually filling our lungs full with air. When we blow all the air out through the tube and catch this exhaled air in the jar above the water, the volume or capacity of our lungs can thus be measured. This we do by reading off the volume of air in the jar. The larger this lung capacity, the more it is indicating that the individual involved is enjoying better health.

17.13. HOW DO WE BREATHE?

- Materials:
1. A large bottle with a rather narrow neck.
 2. A one-hole stopper (fitting in the bottle neck).
 3. A Y-glass tube (or straight tube).
 4. Two small balloons & rubberbands.
 5. One large balloon (or beach ball balloon).

Procedure:

1. Cut the bottom of the large jar out, by covering it with a cm thick layer of hot oil, and touching the outside of the jar with an ice cube exactly at the surface of the oil (the jar will crack and the bottom will drop out). Smoothen the edge by filing or firing.
2. Tie the two small balloons to the ends of the Y-tube with the rubberbands. Hold the long end of the Y-tube through the jar neck and insert the one-hole stopper over the Y-tube and in the jar neck.
3. Cut the large balloon in half, stretch it over the open bottom of the jar and tie or tape it around airtight (it represents the diaphragm).
4. Pull the center of the diaphragm up and down and observe the balloons expand and collapse.

Questions:

1. What does the Y-tube represent in this demonstration?
2. What do the small balloons and the stretched rubber sheet represent?
3. What made the small balloons expand?
4. What stage of the breathing could the expanded state of the balloons be compared with?
5. How different would it be to compare the glass jar with our chest cavity? How are they the same?

Explanation:

The Y-tube in our demonstration represents the bronchial tube, the small balloons the lungs, the rubber sheet the diaphragm, and the jar the chest cavity. This latter one, however, can be expanded or contracted through the flexible rib joints, which is not the case with the glass jar. By pulling the rubber sheet down, the pressure inside the jar decreases, thus sucking the air from outside into the small balloons (inhaling).

HUMAN BIOLOGY

DIGESTIVE SYSTEM

17.14. TURN A CRACKER INTO SUGAR

Materials: 1. Unsalted and unsweetened crackers.

Procedure:

1. Distribute one cracker to each student.
2. Let them chew the cracker without swallowing it for a minute or two.
3. Ask them the following questions.

Questions:

1. How did the cracker taste in the beginning of the chewing?
2. How did the cracker taste at the end of the chewing period?
3. What was the cracker mixed with in your mouth?
4. What does your saliva do to the cracker while chewing?
5. What agent in your saliva breaks down the starch molecules?
6. Are sugar molecules smaller or larger than starch molecules?
7. Why is it better to chew food a little longer before swallowing?
8. What would happen if we almost did not chew our food?

Explanation:

The cracker that was put in the mouth consists of carbohydrates (starch). This being unsalted and unsweetened, will taste quite bland in the beginning of the chewing period. While the cracker is being pulverized into the pulpy mass called a *bolus*, the digestive juice of the salivary glands begins a breakdown of the carbohydrates. An enzyme (*amylase*) in saliva splits the molecules of starch into smaller molecules of sugar. This enzyme cannot break down starch particles that are still enclosed in their natural cellulose envelopes, therefore starches should be cooked before eating.

Another purpose of the saliva is to provide moisture needed by the taste buds. Saliva also has a cleansing action on the teeth. It washes away food particles that otherwise might provide a home for bacteria.

By chewing food a little longer before swallowing, it gets mixed more thoroughly with our saliva, providing an opportunity for the enzymes to break down the large starch molecules, and by the time the food reaches the stomach and the intestines, it can be easily digested.

17.15. TRY DRINKING WHILE STANDING ON YOUR HEAD

- Materials:
1. A glass of drinking water or juice.
 2. A bent drinking tube or flexible drinking straw.

Procedure:

1. Ask one of the students to assist you, to put the straw in your mouth as soon as you are ready to drink.
2. Try to stand on your head against the wall (if this is not possible, bend from your waist down until your head touches the floor).
3. Have your student assistant bring you the glass and straw so that you can drink from it.
4. Suck through the straw while your body (or upper body) is upside down, and empty the whole glass.

Questions:

1. Is gravity needed to make fluids come down the esophagus?
2. Can we drink water while we stand on our head?
3. How does food go down the esophagus into the stomach?
4. Is the esophagus like a glass or rubber tube going in the stomach?
5. Why did the fluid not flow out of the mouth when drinking upside down?
6. What is the muscle action called, which pushes food into the stomach?

Explanation:

After food is swallowed, it enters the *esophagus*. Here it is pushed along by *muscle action*, which is called *peristalsis*. This movement of the food is carried out by *involuntary muscles*. There are two layers of muscles: the inner layer forms a series of circles around the tube, and the outer layer is longitudinal. When the inner layer contracts, the tube becomes smaller at that point, and when they relax the longitudinal muscles contract. This *alternate contraction and relaxation* of the two sets of muscles push the food along the tube in *peristaltic waves*. This is the reason why food, whether it is in solid or liquid form, may be swallowed with the body positioned in any direction. Gravity has little or no influence on this.

APPENDIX

Table 1. HUMIDITY CHART

Difference between Dry- and Wet-bulb Thermometers

Degrees - C	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
Reading of Dry-bulb Thermometer Degrees - C	Percent Humidity													
17.5	95	89	84	79	74	59	64	60	55	51	46	42	38	33
18	95	89	84	79	74	70	65	60	56	51	47	43	38	34
18.5	95	90	85	80	75	70	65	61	56	52	48	44	39	35
19	95	90	85	80	75	71	66	61	57	53	49	45	40	36
19.5	95	90	85	80	76	71	66	62	58	53	49	45	41	37
20	95	90	85	81	76	71	67	63	58	54	50	46	42	38
20.5	95	90	86	81	76	72	67	63	59	55	51	47	43	39
21	95	90	86	81	77	72	68	64	60	55	52	48	44	40
21.5	95	91	86	81	77	72	68	64	60	56	52	48	45	41
22	95	91	86	82	77	73	69	65	61	57	53	49	45	42
22.5	95	91	86	82	78	73	69	65	61	57	53	50	46	42
23	95	91	86	82	78	74	70	66	62	58	54	50	47	43
23.5	95	91	87	82	78	74	70	66	62	58	55	51	47	44

Table 2. DENSITIES OF SUBSTANCES

Substance	Density (g/cc)
Mercury	13.6
Lead	11.3
Steel	7.6 - 7.8
Aluminum	2.70
Glass	2.4 - 2.8
Glycerine	1.27
The Human Body	1.07 (Average)
Water	1
Ice	0.917
Alcohol	0.794
Cork	0.24
Room Air	1.2×10^{-3}
Hydrogen	8.9×10^{-5}

Table 3. INDEXES OF REFRACTION

Substance	Index of Refraction
Diamond	2.4173
Glass, dense flint	1.655
, crown	1.517
Carbondisulfide	1.6255 (20°)
Carbontetrachloride	1.460 (20°)
Ethyl alcohol	1.361 (20°)
Water	1.33299 (20°)
Ethyl ether	1.00152
Carbondioxide	1.000450
Air	1.000293

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